AEDC-TR-09-P-18

Data Validation in the AEDC Engine Test Facility

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Aerospace Testing Alliance

February 2010

Final Report for Period 1 December 2008 – 30 June 2009

Statement A: Approved for public release; distribution is unlimited.

ARNOLD ENGINEERING DEVELOPMENT CENTER
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UNITED STATES AIR FORCE

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REPORT DOCUMENTATION PAGE						*Form Approved* *OMB No. 0704-0188*
The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS**						
1. REPORT DATE (DD-MM-YYYY) xx-02-2010			**2. REPORT TYPE** Final Report			**3. DATES COVERED** *(From – To)* 1 December 2008 – 30 June 2009
4. TITLE AND SUBTITLE Data Validation in the AEDC Engine Test Facility						**5a. CONTRACT NUMBER**
						5b. GRANT NUMBER
						5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) Patterson, Grant Aerospace Testing Alliance						**5d. PROJECT NUMBER** 10941
						5e. TASK NUMBER
						5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Aerospace Testing Alliance 100 Kindel Drive, Suite B212 Arnold AFB, TN 37389-2212						**8. PERFORMING ORGANIZATION REPORT NO.** AEDC-TR-09-P-18
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) 717th Test Squadron 877 N. Hap Arnold Rd Arnold AFB, TN 37389-5051						**10. SPONSOR/MONITOR'S ACRONYM(S)**
						11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Statement A:** Approved for public release; distribution is unlimited						
13. SUPPLEMENTARY NOTES Available in the Defense Technical Information Center (DTIC).						
14. ABSTRACT All systems and processes require some form of data for operation and decision making. Critical decisions or operations require that a high emphasis be placed on validation of data for its intended use. Data validation techniques have evolved as data acquisition and processing have advanced progressively from analog to digital acquisition and processing. This progression will be examined, and the corresponding efforts toward validation of data will be addressed.						
15. Subject Terms Data Validation, Analysis, Verification, Quality Assurance, Jet Engine, Turbine, Engine Test Facility, Ground Test						
16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**		**19A. NAME OF RESPONSIBLE PERSON** Jonathan A. Lister
A. REPORT	**B. ABSTRACT**	**C. THIS PAGE**				**19B. TELEPHONE NUMBER** *(Include area code)*
Unclassified	Unclassified	Unclassified	Same as Report	77		931-454-6150

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. 739.18

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PREFACE

The work reported herein was conducted by the Arnold Engineering Development Center (AEDC), Air Force Materiel Command (AFMC), at the request of the 717th Test Squadron for Arnold Engineering Development Center, Arnold AFB, TN. This document was prepared by the Aerospace Testing Alliance (ATA), the operations, maintenance, information management, and support contractor for AEDC, AFMC, Arnold AFB, TN. The Air Force Project Manager was Mike Dent, and the ATA Project Manager was Rob McAmis.

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1.0 INTRODUCTION

All systems and processes require some form of data for operation and decision making. Critical decisions or operations require that a high emphasis be placed on validation of data for its intended use. For example, data validation is important in computer science in the process of ensuring that a program operates on clean, correct and useful data. It uses “validation rules” or “check routines,” that check for correctness, meaningfulness, and security of data that are input to the system. Microsoft has data validation software used to validate the data entered into a spreadsheet cell. The EPA has a rigorous validation process for data validation which is used in environmental assessments, environmental impact statements, etc. Invalid environment data can result in erroneous decisions which can be costly to the taxpayer and the US industry and can possibly result in failure to take proper environmental initiatives or to implement proper environmental controls. The organizations involved in forensic studies must ensure that various forms of data are valid for determining causal characteristics of crimes. The US Department of Labor has a validation program to ensure the data entered for unemployment insurance claims are valid. These are only a few examples of the importance placed on data validation in multidiscipline processes and systems.

In the Engine Test Facility at AEDC between 5 and 10 terabytes of data are acquired per year in support of the evaluation, validation, certification, and qualification of turbine engines for use in military and civilian aircraft. The data are processed in engineering units (EU) and other parameters required for engine assessment. The data are processed, displayed, and stored as static, transient, and dynamic data for analyzing engine and component performance, operability, stability and structural integrity. In order that correct and timely decisions are made based on the test results, it is important that the data be validated for their intended use. The intended use of the data is to assess the degree to which the engine meets its design intent or its specification requirements. When engine development or improvement programs meet these requirements, the risk of moving to the next level of flight tests or operational status is reduced. Failure to use validated data could cause a misrepresentation of the risks and result in costly delays and increased costs in multimillion dollar development, improvement, or production programs. Thus, a high emphasis is placed on data validation during the testing process. This report will describe data validation in the Engine Test Facility at AEDC. The report will discuss the historical development and use of data validation techniques, the basic process for data validation setup and execution, the various techniques used to validate data, the evaluation of each technique, and recommended best practices.

2.0 BACKGROUND

Data validation techniques have evolved as data acquisition and processing have advanced progressively from analog to digital acquisition and processing. This progression will be examined, and the corresponding efforts toward validation of data will be addressed for each major acquisition and processing system configuration.

2.1 DATA SYSTEMS AND DATA VALIDATION

Figure 1 depicts elements of the data acquisition and processing systems in the ETF in the 1960 time frame. The first engine tests at AEDC (Ref 1.) used manometer banks to measure steady-state pressure. Vacuum checks (uniformly reducing cell pressure below atmospheric) and ambient scans were performed to check for uniform self-consistent readings and to evaluate any deviations due to pressure line leaks and trapped fluid columns. The manometer banks were photographed to record the manometer readings. These photographs were then used to hand log the pressure levels for analysis. Thermocouple analog signals were indicated on millivolt recorders.

Pressures were indicated on pressure gages. All these readings were hand logged and recorded on paper tape. The paper tape was used for input to a processing computer which converted the millivolt levels to engineering units (EU) and processed the steady-state data point. The engine was characterized posttest by the steady-state data points. Transient data were not available. The data were examined for accuracy before final processing. The primary focus of data validation was to ensure data systems were operating satisfactorily (recorder, volt meters and other measurement calibrations, vacuum checks and ambient scans, etc.) to ensure that component efficiencies, flow functions, fuel flow, thrust and resultant thrust specific fuel consumption were reasonable, and to produce validated final data.

Figure 2 shows a schematic of the data acquisition and processing system as it was configured in 1970. The manometer tubes had been replaced by a mechanical system which indexed pressure ports via a scanning valve system to a single pressure transducer. As the pressures were measured, their output was passed to a computer which performed an A/D operation and sent the digitized data to a computer data recording system where the data

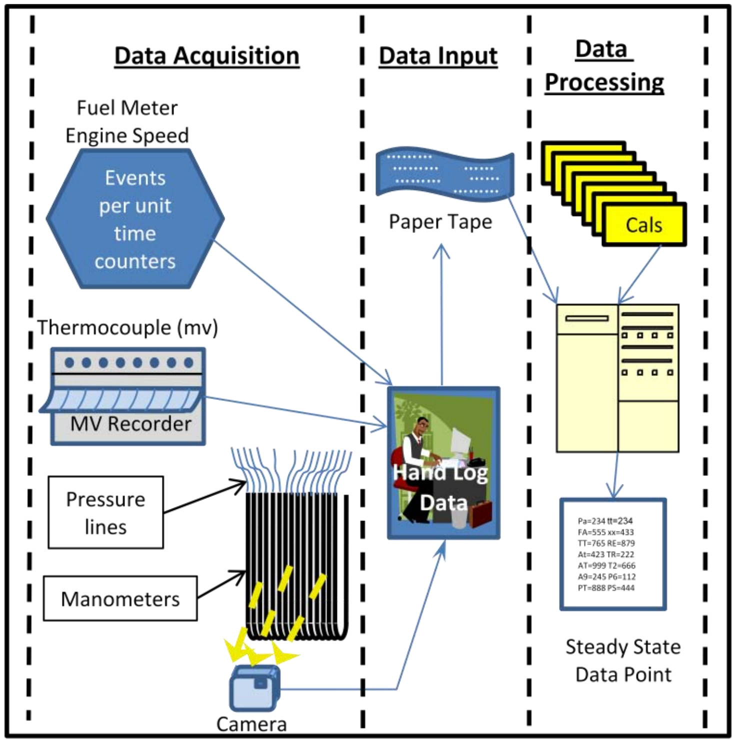

Figure 1. Data Acquisition and Processing Circa 1960

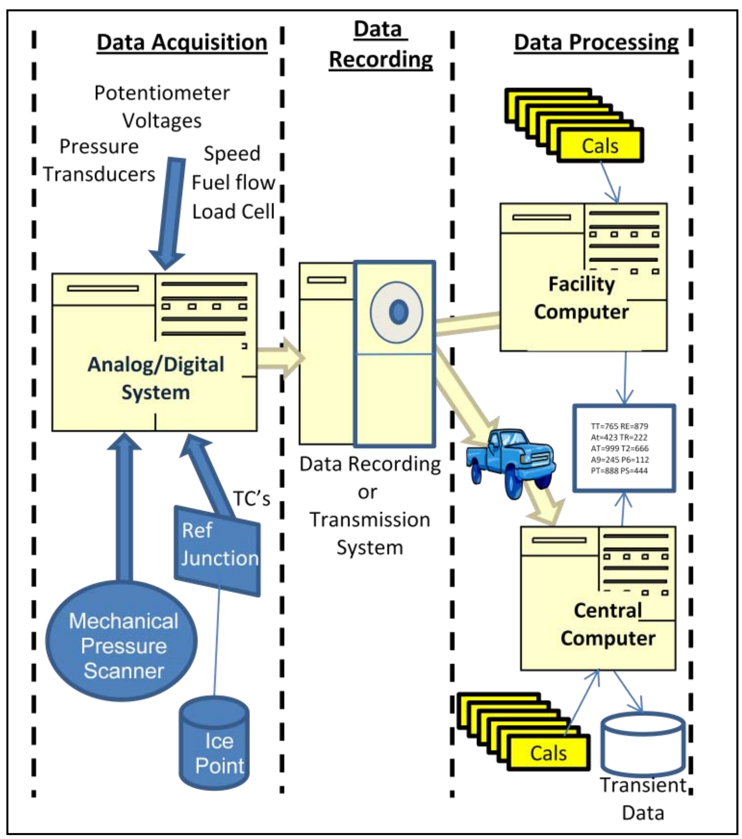

Figure 2. Data Acquisition and Processing Circa 1970

were stored on a magnetic tape. Other measured analog outputs such as individual pressure transducers, thermocouples, potentiometer voltages, load cell outputs, and analog representation of fuel flow and speed were passed to the A/D computer and subsequently to the computer data recording system.

The computer data recording system also transmitted data to the facility computer for data processing and reduction. However, the system could not record and transmit data at the same time, so at times in the test when no data were being acquired the system transmitted the data points to the facility computer. The data were also hand carried to the central computer in the Architectural and Engineering (A&E) building at AEDC where the data were processed for not only steady-state data, but also transient data (~100 samples per second). Because of the delay in processing at the facility computer and the central computer, any data validation initiatives were also delayed. There is no record of any validation except for "eye" scanning of the data for self-consistency and examining various processed parameters for comparison to expected values.

The EU and calculated parameters data were printed on four-part paper, two copies for the manufacturer, one copy for the sponsor, and one for AEDC. This printed output, arranged according to engine and facility measurement stations, engine speeds, fuel flows, airflows, etc., came to be known simply as print pages. These print pages were scanned to assess EU and calculated parameter integrity. The ultimate intent of the data validation process was to ensure that the final data package (a formal submittal after the test of instrumentation lists and processed data) was validated for assessment of engine performance or operability. It was a moment of dread and probably horror for the young engineer when a senior engineer would bring a stack of print pages a foot or more high to the young engineer's desk and ask that the data be validated for accuracy and integrity.

In the late 1970s AEDC began purchasing graphical plotting equipment using a technology known as the data storage tube. This graphics viewer kept the burned image on the screen as other data were displayed. As a result a rather slow serial stream of data could be fed to the graphics viewer. This allowed plot generation of data for validation, i.e., parameter vs. parameter for steady-state data and parameter vs. time for transient data validation. Special software for steady-state and transient data viewing were developed.

The 1980 computer network and processing infrastructure is shown in Fig. 3. The major change in this configuration is the establishment of a network to the central computer and an acquisition computer which

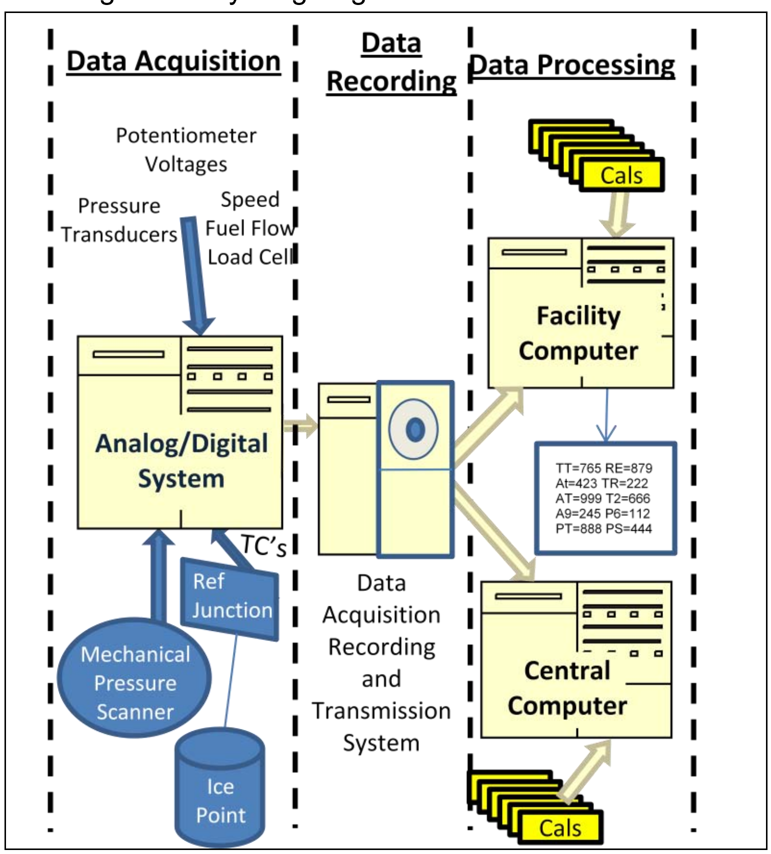

Figure 3. Data Acquisition and Processing Circa 1980

could record and transmit simultaneously. This eliminated the need to move the data manually to the central computer facility. Also with a network connection to the central computer facility the more powerful central computer could be used online to display and process data. This greatly enhanced the capabilities for data validation and ushered in the automated checks for data validation. This architecture (with a few upgrades to the facility computer) remained in place for approximately 17 years. The continued advances and improvements in data acquisition and processing at both the facility computer and the central computer and ultimately data networks brought continued improvement to the validation process.

2.2 AUTOMATED DATA VALIDATION

In 1981, Patton and Chamblee proposed a data check program for the F100 engine being tested in Test Cell T2 (see Appendix A). The objective of the data check program was to reduce or minimize the "eye-scan" method of data validation and to allow engineering aides and technical associates to perform most of the data validation, leaving the engineers to concentrate on analysis. The data checks were incorporated in the steady-state data reduction program with flags in the steady-state print pages for erroneous or invalid data. The data checks included:

- Pretest ambient scans and calibrations (performed by the instrumentation branch)
- Vacuum checks
- Stability of inlet pressure, cell pressure, engine speeds, fuel flow, and load cells
- Comparison of temperature, load cell, pressure, fuel flow, airflow, and geometry for self-consistency (same measured output within a tolerance) among measurements at the same stations, of the same phenomena, or from different data sources
- Comparison of the data to historic data (source used to set check bands or tolerances) and expected component efficiencies
- Determining the measurements which may be the source of errors in efficiencies, airflow, fuel flow, thrust, nozzle velocity coefficient, etc.

In 1986 Warwick gave a presentation on data validation to a potential test customer (see Appendix B) that was a more comprehensive approach to data validation than had previously been available. The planning stage called for the securing of estimates for measurements and parameters including thrust, fuel flow, component performance, engine/control system logic/limits/stability, facility capabilities/limits/stability, the accuracy or uncertainty of the measurements, etc. Estimates were obtained from math models, engine specification, engine of same model, OEM sea-level check of engine, other engine/component tests, theoretical limits, manufacturer's instrument accuracy, knowledge of test facility and engine capabilities, limits and stability, test experience with instruments/sensors, and data bank or experience. Computer software was then programmed to make checks of specified limits or ranges, compare duplicate measurements and profiles, and assess signal quality. Flags were generated for discrepant measurements and a summary was printed. Computer-generated plots were also made of overall/component performance and profiles for expected behavior. Any deviations were further investigated for data errors. Priorities in validation were signal quality, facility and engine stability during acquisition of data points, facility set conditions, engine set conditions for loads and control settings, and measurements and calculations integrity.

In 1993 a two volume resource titled “AEDC Turbine Engine Data Validation Handbook” was written at AEDC. The first volume of the handbook described a number of validation checks, but it was not as comprehensive in its treatment of data validation as the Warwick presentation mentioned earlier. However, the handbook did call for attention to calibrations and measurement uncertainty in relation to data validation. The second volume was a listing of the subroutine DATVAL. The DATVAL subroutine was a more complete set of validation checks than defined in the document by Patton and Chamblee but was still specialized for the F100 engine. Although the document called for the changes and updates to be compiled and issued at the end of each fiscal year, no changes or updates were ever made.

2.3 CHANGES IN SYSTEMS TO THE PRESENT SYSTEMS

In the mid 1990s several changes were made to the data acquisition, processing, storage, display, and validation environment. An ETF Analysis Capability Upgrade Project replaced the Central Computer as a data source for data validation and analysis with local network file servers, local processors, and work stations. The local network was the predecessor network of the Propulsion Data Processing and Analysis System (PDPAS). New software for viewing data on the work stations was developed on UNIX platforms. The software was developed with an advanced set of requirements from data validation and analysis personnel. The resultant graphic viewer entitled Test Interface Graphical Evaluation Resource (TIGER) was a superior state-of-the-art data plotting and manipulation software program which offered an improved interface to data for validation. Between 1994 and 1998 the data acquisition systems in the engine test cells were replaced by the Engine Data Acquisition and Processing System (EDAPS) (Ref. 2). EDAPS is fundamentally the same in all test cells, but because each test cell has different capabilities and missions, each installation also has several unique features. These customer-unique test missions are constantly making new demands on the data system. In order to support the various and constantly changing requirements, EDAPS was developed with a modular plug-and-play design. A block diagram of the EDAPS and PDPAS is shown in Fig. 4.

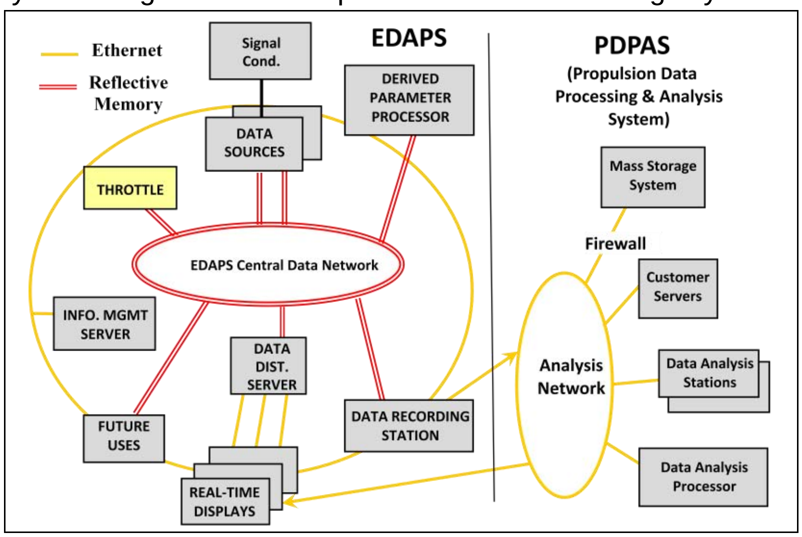

Figure 4. EDAPS and PDAS Data and Analysis Systems

The EDAPS architecture includes a central data network which contains, communicates, and routes the test data through a reflective memory system (near real-time distribution of data to various system interfaces of the central data network) to the engine throttle system, the data sources (pressure measurements, temperature measurements, etc), the derived parameter processing computers, the data recording system and the data distribution servers. The data distribution servers route data to the real time displays and the data recording system sends data to the PDPAS. The information management server provides setup information for all software applications; maintains the test log, discrepancy log, event log, and calibrations; and maintains system configuration. Data are recorded in engineering units.

In the same time frame and complementary to the EDPAS, the enhanced PDPAS was deployed with all processing of data on the local PDPAS network. This system replaced and enhanced the processing and routing of processed data to AEDC data analysts and AEDC customers, both local and remote.

2.4 THE DATA VALIDATION MANAGER

In 1998 work began on the Data Validation Manager (DVM). The data validation manager had the goal of applying all of the data validation checks and methods into a system which validated the EDAPS continuous data stream, thus ensuring that the data points taken were processed using validated EU data. In addition to incorporating all the known checks and methods, the DVM had a setup wizard which set up the checks with limits and tolerances, a maintenance wizard which detected new measurements and parameters in the test instrument databases, an integrated man-machine interface with visual display of facility and test article instrumentation locations, audible and visual annunciation of valid and non-valid test conditions, fault indicators with corrective action options, setup wizards, a supporting database viewer, and event data plots. Several attempts were made at implementing the DVM, but several problems prevented its deployment. These included the delay in implementing the real-time validation module, the time required to set up the data validation checks, communications with EDAPS which frequently was dropped leaving the DVM useless until communication was restored, resistance to change in the data validation culture, and the lack of a champion for the DVM among the ETF analysts. In addition, ETF analysts began to rely on annunciators and other capabilities of EDAPS for data validation and did not move to the DVM. Thus, an investment of several $100K did not realize any of the intended benefits.

3.0 THE DATA VALIDATION PROCESS

The basic techniques of data validation as set forth by Patton and Chamblee and later Warwick have not changed. There is still the need to evaluate the measurement distortion of measured parameters at the same measurement station, compare the same measurement from different sources, evaluate measured data in check bands, ensure the stability of an acquired data point, compare data against estimates, evaluate signal quality, compare component and engine performance to expected values, and validate data in priorities in accordance with test objectives. These basic techniques have been incorporated into improved methods for validation.

Basic systems used for data validation are the EDAPS and the PDPAS. These systems are used to house the displays of data for validation, the DEU, steady-state and transient data reduction programs, and the data plotting and graphics program TIGER. The advent of spreadsheet capabilities has recently been used to aid in the setup of these systems.

3.1 DATA VALIDATION TECHNIQUES

Data validation techniques are designed to identify two basic classes of measurement failures, 1) in-range failures and 2) out-of-range failures. Out-of-range failures are typified by a negative pressure or a temperature that reads highly positive or negative, or any value which falls outside the expected measurement range. Most out-of-range failures will be captured by in-range data validation techniques. Therefore, this report will only address the in-range failure identification techniques of data validation. The in-range failure identification techniques are discussed as follows.

3.1.1 Self-Consistent Data Sets

There are two classes of data which fall into self-consistent data sets. The first are measurements of the same physical phenomena in a series measurement such as load cells for measuring engine thrust restraint scale force, the output of fuel meters for measuring fuel flow, and the measurement of inlet airflow to the engine. These measurements are usually compared to one another through a difference calculation, and the difference is assessed for compliance with the expected uncertainty of the measurements. For instance, typical load cell output difference should be within 0.03% of full-scale reading, fuel flowmeter frequency output difference should be within 0.02% of full-scale reading, and airflows should be within 0.25 to 0.5 % of reading. A typical plot of load cell bridge agreement is shown in Fig. 5. The bridge output agrees within ±15 lb_f which corresponds to a ± 0.03% of full-scale output.

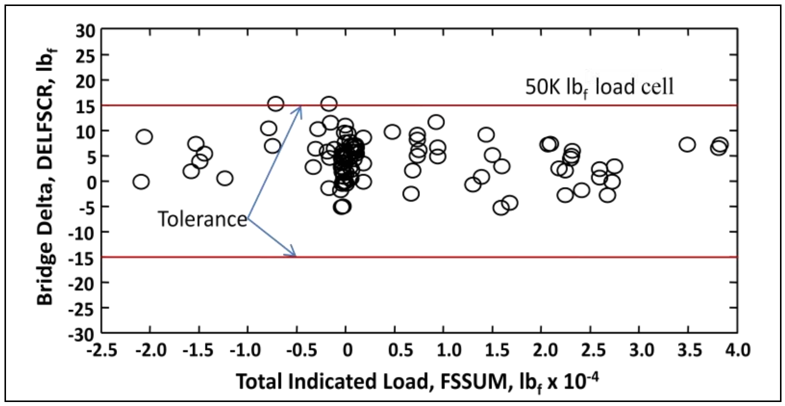

Figure 5. Load Cell Bridge Difference

The second class of self-consistent data sets is measurements which are distributed over an area where the measurements are input to an average value for the area or region. Such data sets are the pressure measurements from an instrumentation rake at a station point in the engine, the plenum pressures in front of the inlet bellmouth, or the temperatures at similar measurement locations. These measurements by nature will be imprecise or distorted due to flow profiles and heat flux distributions. The distorted degree or level will be an indication of how well the measurements represent the plane or region average value. This level of distortion is formulated as the measurement distortion level (MDL) and is given by

$$MDL = \frac{(X_{max} - X_{min})}{X_{avg}}$$

If the MDL is higher than an expected value, then the data set is examined for possible invalid data. The limit for acceptable or expected MDL is set by knowledge of expected profiles over the area or region of measurement and by previous experience. A typical example of a data set measurement distortion is shown in Fig. 6. Note in Fig. 6a the change in MDL from the ring close to the centerline and the ring close to the wall. The influence of the wall and the individual radial profiles causes a spread in the data near the wall resulting in higher values of MDL. The actual ring pressure levels are shown in Fig. 6b. The spread in the data is seen to produce the higher value of MDL. As a result the centerline MDL limit could be set at a relative small value (i.e., 0.004%) whereas the wall MDL limit would set at a larger value (i.e., 0.04%). Any MDL beyond these limits would be cause to examine the pressure measurements for possible invalid data. If the data are not found to be invalid, then the MDL limits may have to be increased.

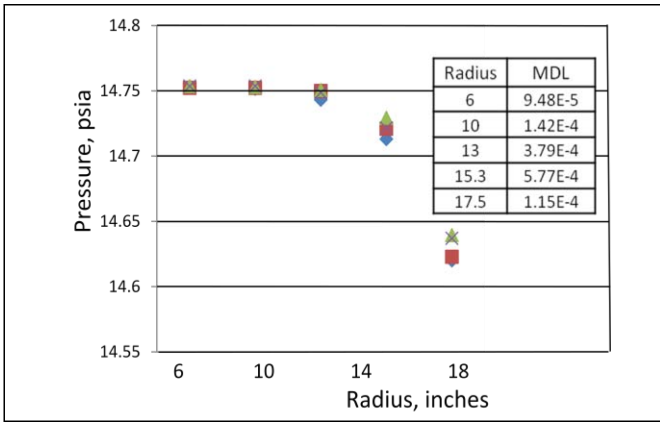

Figure 6a. Inlet Measurement Distortion

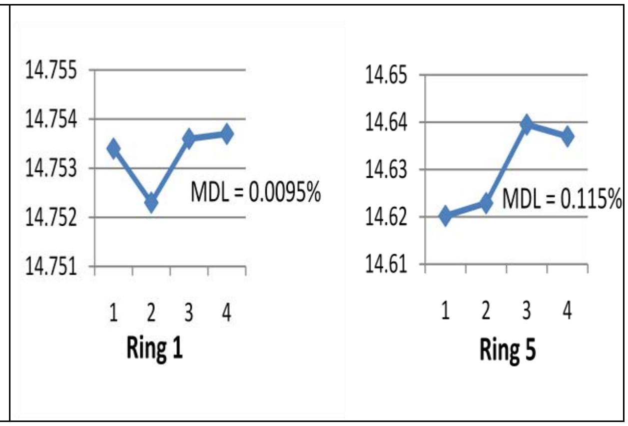

Figure 6b. Near Wall and Centerline Distortion

Figure 6. Measurement Distortion

3.1.2 Different Data Source Comparisons

Comparison of measured data from multiple sources provides a degree of validation for data from one or all of the measurements. Perhaps the most important application or multiple source validation is for pressures. This validation usually consists of comparing steady-state measurements of pressures with low uncertainty (pressures from the pressure scanning system) to other measurements from transducers with a response of 10 to 20 Hz to measurements with a response as high as 1,000 Hz. These measurements may be directly compared by a difference value limit which is set based on experience and the expected uncertainty of the transducer. A normalizing procedure produces a better defined, more general limit for the validation of the transducer. A typical validation result is shown in Fig. 7 with the normalized parameter

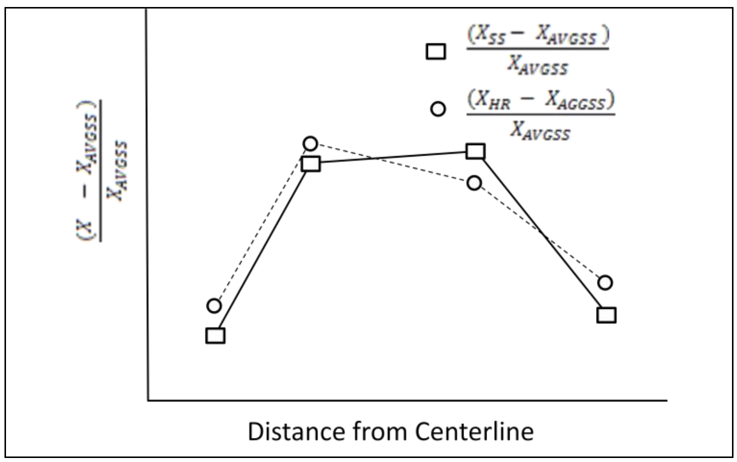

Figure 7. High-Response/Steady-State Comparison

$$HRSSNOR = \frac{(X_{HR} - X_{AVGSS})}{X_{AVGSS}}$$

Other multiple source comparisons include engine digital control parameters usually acquired into the data acquisition system through the control unit's data bus. These parameter comparisons may include burner pressure, inlet total pressure, turbine inlet pressure, and turbine inlet temperature. Comparisons are also made between conventionally acquired measurements and direct transducers which transmit data directly to a test control system (i.e., the throttle computer). Finally, comparisons may be made between temperatures acquired from different reference systems.

3.1.3 Comparison to Prediction

Comparison of measured data and parameters to predicted values is important in ensuring valid data. As has been previously discussed the predicted uncertainty and measurement distortion including predicted profiles are important in setting limits for self-consistent data set validation. For engine performance and operability predictions, comparison of measured data and parameters to predicted values will reveal invalid data, an error in the prediction, or a deficiency in the engine design. Prediction of overall engine and component performance are also important to validation. For example, predictions of thrust and thrust specific fuel consumption (TSFC) are important in assessing whether an anomaly in these parameters is due to an error in the prediction or invalid data associated with the measurements of airflow, pressures, scale force, and fuel flow which form the thrust and TSFC calculations. A typical comparison of measured and predicted thrust and TSFC is shown in Fig. 8. Likewise the component performance characteristics are important in comparing measured and predicted values. Component maps incorporated in engine math models will indicate component pressure rise or pressure drop and temperature rise or fall due to thermal efficiency, the compressor speed line match, and the airflow prediction versus engine speed.

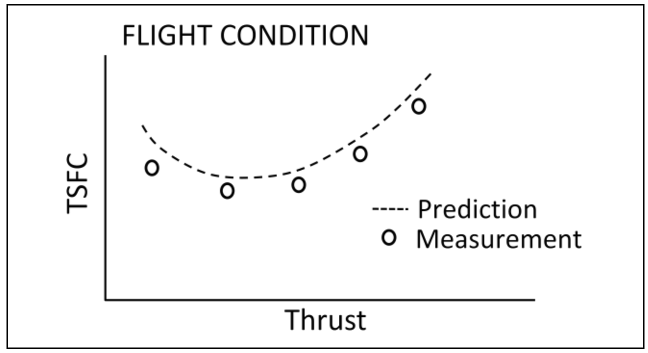

Figure 8. Engine Performance Comparison

Other predictions of limited engine operation are important to ensuring anomalies are due to engine response characteristics and limits and not invalid data. These predictions include the expected start regions for windmill and spooldown air starts and regions of other limited engine operation (i.e., augmenter lightoff and stable operation). Operability predictions of time to thrust and time to thrust cancellation are important in identifying close-coupled measurement response problems.

3.1.4 Comparison to Previous Data

Data available in the AEDC archives on ETF local drives (steady-state data) or the mass storage system are used to compare data of a current test with data from previous tests. Much of the confidence in data arises from comparing or viewing data from previous test periods or test programs so that the data can be viewed in relation to the aggregate display of historical data. This is useful in validating venturi airflow, inlet airflow, MDL limits, fuel flow, multiple data source comparison limits, and engine and component performance characteristics. Comparison to previous performance characteristics may also be viewed as an analysis tool. However, the discrepancies in engine characteristics may indicate a discrepancy in the engine hardware or controls.

Historical data can be grouped into two types. The first type of historical data is the data from a previous test period in the current test program. This type of historical data represents the least risk of use in data validation since the facility and engine configurations are mostly fixed. (There may be minor changes in the engine configuration.) The second type of historical data is the data from a previous test program of the same engine or the same facility configuration. When data are used from a previous test program, care must be taken to ensure that a change in the engine or facility test configuration does not negate the use of previous data for data validation. A typical use of historical data is shown in Fig. 9. The airflow measurement venturi inlet total pressure MDL is displayed for a current test along with the MDLs from previous tests. A least squares fit of the data is shifted as shown as a limit for the MDL values. If the current data falls within the context of the historical or the tolerance curve it is assumed to be valid.

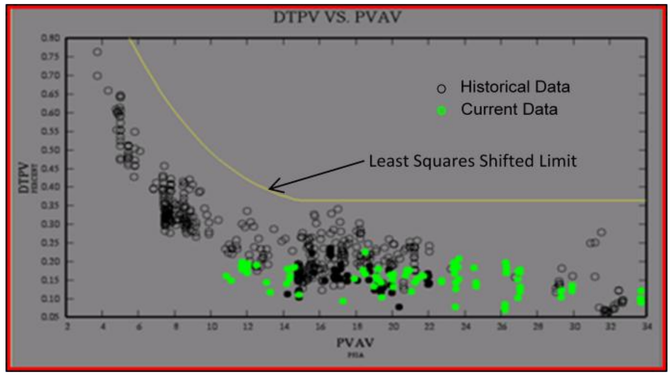

Figure 9. Historical Data Comparison

3.1.5 Correlation with Other Measurements

Many times a measurement is isolated such that an attempt to validate the data by comparison to a predicted value or self-consistency data validation technique cannot be used. In this case a correlation may be developed with other valid data to assess the validity of the isolated measurement. For instance, if an isolated pressure measurement is located in the bore of the compressor, then it will probably be less than the compressor exit pressure and greater than the compressor inlet pressure. But neither comparison to the inlet or exit pressure will provide adequate validation for the bore pressure. However, if the normalized difference between the compressor exit pressure and the bore pressure is formulated and this difference is plotted over a range of speeds and altitude conditions, a correlation between the two pressures may be found which will allow validation of the bore pressure. Figure 10 shows an example of a mid compressor isolated pressure measurement. By forming a ratio of the mid compressor pressure to the compressor exit pressure, a linear correlation was developed for verifying the validity of the mid compressor isolated pressure. The correlation technique may involve a nonlinear fit to the data for a more complex correlation. In any case the correlation method of data validation may be the only technique available for validation of isolated measurements.

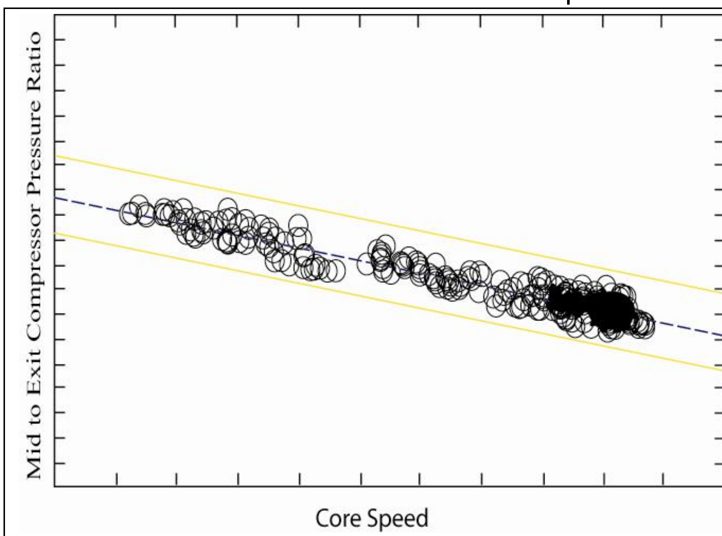

Figure 10. Isolated Parameter Correlation

3.1.6 Assess Compliance with the Laws of Physics

All measurements of physical phenomena must adhere to the laws of physics concerning the relationship between measurements. For instance, the total pressure and temperature cannot increase in the direction of flow in an adiabatic passage with no work input. Therefore, for an adiabatic passage flow, if an upstream total pressure or temperature is higher than the downstream total value, then the upstream or downstream measurements will be suspect of being invalid. In any compression process involving airflow the total pressure and temperature must increase. The static pressure at any point in the flow field cannot be greater than the total pressure. These observations may seem obvious, but for automatic checks in data validation the “laws of physics” checks must be put in place.

3.2 DATA VALIDATION PROCESS ELEMENTS

Planning for data validation is critical for data validation success. Planning includes gathering validation estimates; identifying parameters for validation techniques; ensuring data acquisition, display, and plotting systems are setup for validation; ensuring a correct instrumentation requirements list (IRL); and setting of validation priorities based on test objectives.

3.2.1 Measurement Estimates

All data must be validated against some criteria or estimates. Data are usually evaluated for self-consistency or against an estimated value. Estimates in various forms are required to assess the correct or expected value of a measurement. Each of the estimates must be established prior to test in the planning process.

3.2.1.1 Need for Measurement Estimates

Tests should be run only if the expected result of the test is known because without an expected result, the test can only establish unanticipated values and there is no criteria for test objective completion. Expected results imply expected values or estimates. For an aircraft turbine engine test the required expected values may be thrust, fuel flow, and airflow. However, if the thrust and thrust specific fuel consumption (thrust/fuel flow, TFSC) have expected values, then there must be expected values of engine inlet and exit pressures and temperatures and efficiencies. These expected values and other reduced parameters are also required not only to validate the test with the expected result, but also to ensure that the data are validated for their intended use. Other estimates that are needed are for comparing multiple measurements of the same physical quantity. Other estimates may also be needed for the expected data dispersion from multiple measurements in the same measurement plane in the engine. Thus estimates in various forms are needed to validate not only the test, but also the data of the test.

3.2.1.2 Type of Estimates

Estimates fall into two types: 1) the estimated expected level of a parameter at various operating points of the engine and 2) the expected dispersion of measurements. The expected levels are usually performance parameters of the test article or the facility. Typical are thrust and fuel flow for the engine and facility-produced inlet airflow pressure and temperature at the engine inlet. However, as mentioned previously these performance levels require other expected levels of engine and facility component performance. If the expected value is not close to the estimate, then invalid data may be suspected (or may indicate engine design deficiency). Other performance levels are indicated by component efficiencies and pressure rise or pressure drop. Facility airflow is indicated by various flow measuring components which when calibrated produce expected values of airflow based on temperature and pressures of the measurement component. Any discrepancy in airflow will bring the to accuracy of the component pressure and temperature measurements into question.

The expected dispersions are of two subtypes: a) the dispersion due to the uncertainty stack up of multiple measurements of the same physical quantity and b) the dispersion due to flow field effects. Scale force measurement is an example of the former and an engine station survey of the latter.

Scale force is measured by a load cell in series with the thrust load train. The load cell bridges (measurements in a bridge arrangement on both sides of the load cell column) are expected to provide measurements whose differences are within the uncertainty of the overall load cell uncertainty. The same argument applies to multiple fuel flow meters in series.

When measurements in a plane or station are considered, the plane has an average value, but due to flow boundaries and different pumping ratios the dispersion is greater than the uncertainty stack up of the measurements. If the measurements have a known profile, then this profile becomes part of the estimate for the expected values across a measurement rake in an engine plane.

3.2.1.3 Source of the Estimates

Securing the estimates for use in data validation can be one of the most daunting tasks of the data validation process. The estimates may come from various sources and in various forms. For a new engine, some calculated parameters such as thrust, fuel flow and component efficiencies may be available in engine specifications or from previous engine or component tests. The overall engine performance will be dependent on the test or flight condition. While one value of specified performance may be available at the engine design point, other conditions at off design may not be available, particularly for new engines. Some manufacturers have used the steady-state math model to provide specified performance estimates at all points in the envelope. However, the accuracy of the math model may not be adequate for validation until it is certified from engine test data. Other estimates may be obtained for tests of similar engines in particularly the expected distortion and profiles at specific measurement stations. The expected measurement uncertainty is used as a validation criteria in either a 1-sigma, 2-sigma, or 3-sigma (sigma is a standard deviation) expected limit.

If the test is a repeat engine test, then most of the estimates will be available from the history data of the previous test. In fact most of the limit estimates for individual measurements will have been empirically refined in the data validation process of the previous tests. Care must be taken to ensure that estimates are modified for any measurements associated with component or controls modifications. The math model, if available, should have been certified for use from previous tests and may be used for additional validation estimates, particularly component efficiencies.

3.2.2 The Instrumentation Requirements Sheets

Instrumentation requirements must be delivered for the engine or prepared for the facility. The requirements have assumed various forms in the past, but today the instrumentation requirements are in the Instrumentation Requirement Sheets, which consist of individual sheets or requirements in a spreadsheet workbook. Each page in the workbook describes some part of the instrumentation, data acquisition, processing, and display systems. If there are errors in the IRS, then invalid data may be processed.

3.2.2.1 Instrumentation Requirement Sheets Description

The Instrumentation Requirements Sheets contain all the information necessary to set up the acquisition systems to acquire the data, patch the instrumentation to the data sources, define the operational limits, and set up the parameters in steady-state and/or transient acquisition data points. Requirements for special instrumentation (e.g., close-coupled transducers, high-response pressures and strain gages, etc.) are also provided on separate sheets in the workbook. The field definitions of the instrumentation requirements list (IRL) of the IRS are shown in Fig. 11. The list includes the parameter name, description, ranges, data sources identification (i.e., brick panel), scan rate, type of data point, routing to the throttle system, alarms, and comments. Although all the requirements information is specified in the parameter list, the IRS also includes summary pages of special instrumentation, controls information, Hoke panels, brick panels, Universal Temperature References (UTR's), and digital temperature scanners layouts and patch routing information.

STATUS	REV NO	ENGINE	PARAMETER	DESCRIPTION	LOW RANGE	HIGH RANGE	UNITS	ANGLE	UTR	ENGINE HOKE	AEDC HOKE	BRICK PANEL	TACS	EDAPS REAL #	SENSOR TYPE	DATA SOURCE	DTS	INSIDE/OUTSIDE CELL	SCAN RATE	SS REQUIRED	TRANSIENT REQUIRED	FILTER	RECORDER	THROTTLE	ALARMS				COMMENTS
																									LOW WARNING	LOW LIMIT	HIGH WARNING	HIGH LIMIT	

Figure 11. Instrumentation Requirement List Headers of the IRS

3.2.2.2 Accuracy of the IRS

The IRL contains all of the information for setup of data sources for acquisition of the data. The IRL includes an indication of engine or facility parameters and the parameter name, description, range, units, patching, sensor type, data source, limits, etc. The data acquisition system is set up according to the IRL, and if there are errors in the IRL, then the data acquired will not be valid. The IRL is checked for the correct parameter name, any duplicate names, any missing parameters, any duplicate patching assignments, the proper scan rate and filters, and the correct data source. Any discrepancies should be reported to the instrumentation engineer for correction.

The IRL may also be the source for determining the measurement location. The measurement location may also be available from instrumentation sketches. Each measurement location should be known. This is required to assess valid parameters in terms of their location in a rake profile, the known flow characteristics that exist between parameters, the measurement values based on the measurement location in the engine or facility, etc.

3.2.2.3 Instrumentation Grouped by Objective

Instrumentation which delivers data critical for a specific test objective is identified, and the validation requirements for these data are implemented. In setting the priorities for data validation by test objective, the identification of data sets by test objective is required. These data sets may consist of EU and calculated parameters. If engine and component performance are test objectives, then the data defining thrust (will include inlet airflow), TSFC (will include engine fuel flow), and component performance and efficiency will be identified for performance test objective data validation. If augmentor stability is a test objective, then the parameters of interest for objective data validation may include augmentor fuel flow, high-response pressures, core and fan duct air flow values, fuel/air ratios, liner pressure delta, augmentor inlet temperatures and pressures, flameholder approach velocity, and other stability critical parameters. All instrumentation should be evaluated for how it is used in the various test objectives either in EU form or as supplied for further data reduction for test objective critical parameters.

3.2.3 Data Reduction Software Programs

Data reduction software programs which produce the calculated parameters for evaluation of test objectives must be carefully set up or invalid results will occur. The data in EU form may be valid, but if there is an error in a calculation, then the calculated result will be invalid. Processing of calculated parameters is normally accomplished by using the Turbine Engine Test Analysis Standard (TETAS) subroutines (Ref 3). Use of these standard subroutines requires that only inputs and outputs be correct and eliminates the possibility of a programming error. This is also supplemented by user-peculiar calculations. Data are processed through the Derived Engineering Units (DEU) program (also includes online calculated parameters) and the steady-state and transient data reduction programs. The DEU program acquires measured data from the EDAPS current data table and from these measurements provides calculated parameters for online display. Steady-state and transient programs use the entire EU data set transmitted to the analysis network for processing. Invalid results in EU or calculated parameters can result in test program delays and misintrepretation of test objective completion. It is important that the programs be thoroughly checked out prior to test and that any corrections be made prior to test.

3.2.3.1 Setting Up Fuel Flow

Most calibrations are applied to the instrumentation prior to acquisition of the data. This includes all temperatures, pressures, and thrust load cells. However, the fuel flowmeter calibrations are set up in the data reduction programs. These calibrations are acquired from fuel meter calibrations at the AEDC Precision Measurement Evaluation Lab (PMEL). The delivered calibrations are in terms of plots of Roshko number versus Strouhal number. The plots are formulated into lookup tables such that inputs of Roshko Number (meter frequency/kinematic viscosity) will yield a K factor (meter frequency/volume flow rate) which is related to the Strouhal number by a constant for a given meter. Care must be exercised in setting up the fuel flow calculations since any errors in interpreting the plots into lookup tables and resulting calculations can result in invalid fuel flow.

3.2.3.2 Calculation of Parameters for Validation

Calculation of parameters such as thrust, fuel flow, and other higher level parameters allows the comparison of these outputs to expected values or estimates. Any deviation from the estimate may be due to invalid data input into the calculation. Likewise the MDL calculations in the steady-state data reduction program with appropriate limits allow evaluation of the MDL and the generation of an error flag if the MDL is beyond a preset limit.

3.2.3.3 The PPC File

Each parameter (acquired or calculated) is assigned a location within a master data array. That location is referred to as the parameter's item number. This is accomplished through the Performance Parameter Compilation (PPC) File which aligns parameter names with item numbers, units, data formats, etc. This file is either set up line by line “by hand” or through an EXCEL program which automates the process. Errors in PPC file setup will cause improper assignment of data to calculations and displays. Thorough checkout of the data reduction programs prior to test is required to correct any errors in calculations and the PPC files.

3.2.4 BDS Screens

Base display screens (BDS) (of the EDAPS) display test parameters that are displayed in rows and columns of tabular data, in annunciator windows, and in running graphics of PLA, speed, variable vanes, etc. These displays are in the form of large 42-in. LCD displays in the online data analysis rooms and in the screens of workstations in the test facility. The large 42-in. displays are used not only for data validation, but also for equally important functions of test operational and situational awareness.

3.2.4.1 Importance of BDS Screens

The displays of the BDS are the primary first check for data validation. As the data are required, the displays are updated in real time. The displays receive data from the EDAPS real-time data stream and the DEU program via the EDAPS current value table. The BDSs are set up in individual pages of rows and columns or in graphic annunciators. For parameters which have specified limits, the BDS will display the parameter in a color depending on the low-, mid-, or high-range limit for the parameter. It is these color limits which first alert the data analyst that there is a possibility of invalid data and that further examination of other parameters in the BDS displays or the steady-state data point print pages are required. The BDS display parameter limits have constant values–high or low. This limits the capability of the BDS displays for data validation when the real parameter limit is nonlinear. A recent change to the limits applied to the BDS allows the use of nonlinear or piecewise linear limits in the BDS. This greatly enhances the BDS not as just a first look at data validation; for the parameters displayed, it may approach the final definitive data validation process.

3.2.4.2 Screen Area Setup for Test Monitoring and Data Validation

A typical layout of the large 42-in. BDS displays is shown in Fig. 12. This particular screen layout has display areas devoted to data validation, engine control, and lube system operational awareness and situational awareness. The layout of the displays follows a general display standard as shown in Fig. 12, but the display may be modified to suit the particular requirements of the test team. For instance, there may be special support systems information which replaces a section of the field in the standard layout. The BDS display is set up according to the critical objectives and systems for the test.

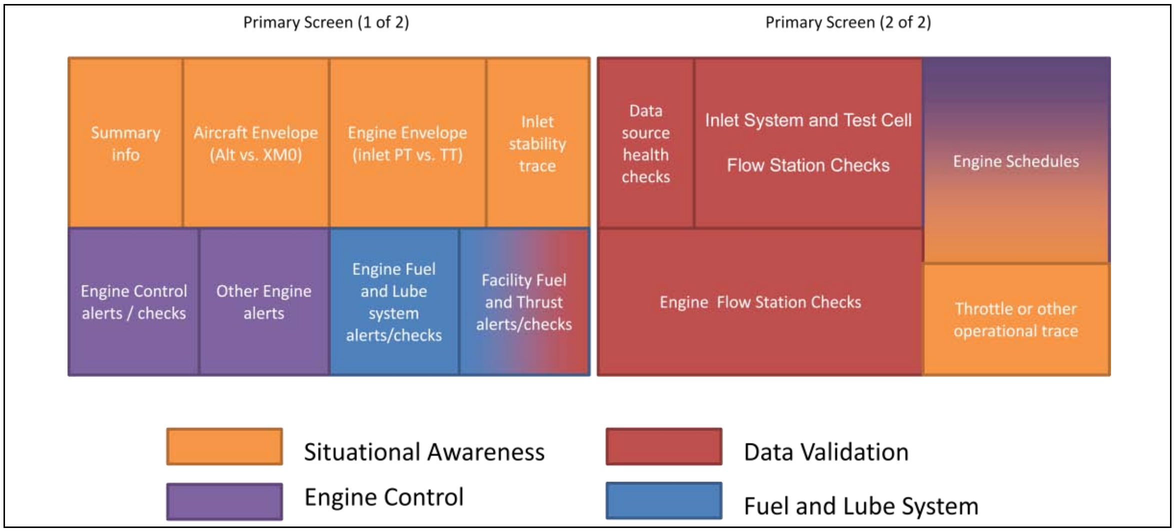

Figure 12. Quasi-Standard BDS Large Display Layout

3.2.4.3 BDS Screen Setup Information

BDS setup information includes the parameters to be displayed, the limits applied to the display parameters, the location of the parameters on the screen, and a background graphic. The parameter limits come from the EDAPS data base. These limits are assigned in the IRL in the limits or warning fields of the IRL. If the limits are constant, the constant limit is placed in the limits field. The constant limits can also be temporarily defined at the BDS display. If the limits are nonlinear, then parameter names are placed in the high- and low-limit fields of the IRL. The nonlinear limit is set in place for a particular display parameter by calling a function or subroutine from the DEU program which has the name of the high- and low-limit parameters set in the IRL for the display parameter. The limit is then applied to the display parameter in the BDS display. Each parameter may have its own individual high and low nonlinear limits.

The remainder of the setup is accomplished via the BDS display client. The BDS client is similar to multiple document applications such as some of the older Microsoft Office applications. Once the application has been started personnel may begin to add display units which appear as sub windows within the application's window. A new display unit may be added via the applications menu. Once a new display is requested a dialog screen will then appear prompting for the choice of a tabular, annunciator, parameter vs. parameter, or mimic (bitmapped image) display. The tabular selection will enter a screen where a parameter name vs. value tabular display can be set up. Each instance of the BDS client may have any number of the available display units mentioned earlier.. The mimic display unit is rarely used in data validation displays. It is more likely to be used on a display of operational or situational awareness. Once the personnel is satisfied with the arrangement of the display units the whole configuration is saved so that it can be retrieved. Multiple BDS configurations may be used to provide a display for different purposes. The configuration can then be retrieved for any BDS client the user is logged-on to. Because of the large screen display area, the 42-in. displays are set up at PCs using one of the large displays as a monitor. As a result the setup must be accomplished in the data analysis room where the large screens are located.

3.2.5 Print Pages Setup

As noted previously, print pages of measurements and calculations have been used in the validation process for the last 40 years. They are basically unchanged in that they have groupings of parameters to aid in the validation of data and calculations. At present the print pages are rarely printed but are viewed electronically through 5 minutes before start.

3.2.5.1 Overall Print Page Requirements

The overall requirement for the print pages is to print all of the EU and calculated parameters that are required to be validated. To facilitate the data validation, the EU and calculated parameters are grouped by region, area, or other instrumentation location of the measurements. In addition, the data are grouped by measurement type, flight conditions, engine and facility systems and components, validation parameters such as MDL, and other groupings to facilitate validation. Appendix E is a suggested print page standard layout.

3.2.5.2 Index and Summary Page

Scrolling through print pages to find the desired data is time consuming. The index page at the front of the print pages guides the user to the page where the desired information is located. Setup of the index page is as detailed as required depending on the content of the print pages.

The summary page is normally the page immediately after the index page. The summary page typically includes the groupings of data for the facility set conditions, engine set conditions, an engine performance summary, an engine control summary, airflow and fuel flow measurement systems, test cell cooling, bleed and power extraction, and a comparison of the TETAS calculations to customer and engine vender calculations. Other groupings may be displayed at the discretion of the project team.

3.2.5.2 The Check Flag Display

Check flags are generated when data are outside a limit or a test condition is not valid. A summary of these check flags is located on the first page of the print pages. Data validation check flags are also on the page where the data groupings being validated are located.

3.2.5.3 Different Data Source Comparisons

Data source comparisons were described in a previous section. The print pages incorporate groupings of parameters which compare data from different sources. As mentioned previously this may be the comparison of a scanned pressure to a transducer tied to the same aerodynamic pressure line, comparison of control sensed data to other acquired data, or comparison of acquired data to directly transmitted data. The comparisons are displayed to assess the degree of accuracy between different sources.

3.2.5.4 Pressure and Temperature Display

Pressures and temperatures are displayed in the print pages in groupings according to measurement system groupings. For instance all of the temperatures on a given UTR are displayed together along with the ice points and the reference plane temperatures. Similar data from each UTR come under the temperature grouping. The pressures are grouped either in alphabetical order or by pressure scanning units. The pressure grouping also includes the reference pressures.

3.2.5.5 Data Point Stability

A steady-state data point has a requirement for stability of measurements during data acquisition. If the variance of pressures, temperatures, and speeds which define the set conditions for the data point is too high, then the engine and facility are not in an equilibrium state and the data point will not be considered “steady.” The display of stability is usually on an appropriate page with other parameters and is typically displayed as a variance in a table entry under engine and facility set conditions on the print page summary sheet.

3.2.6 Limits

Limits are used in data validation, engine and facility control systems, and in test and test condition validation. They provide an indication of acceptable operation or behavior

3.2.6.1 Purpose of Limits

The general purpose of limits is to provide an indication that the output or behavior of a system is within acceptable bounds. The systems may be measurement systems, engine systems, test support systems, facility systems, etc. The focus here is for the limits in data validation. The purpose of data validation limits is to ensure that measurement systems produce data outputs within boundaries acceptable for the intended use of the data.

3.2.6.2 Types of Limits

The types of limits are grouped according the type of validation criteria being employed. The types of data validation limits include MDL limits, dependent parameter limits (engine airflow) based on an independent driving parameter (usually corrected speed), delta limits for assessing agreement of fuel meters and load cells, parameter ratio limits, control input vs. output limits, limits between the same measurement from different sources, level limit for the normalized difference between two parameters which respond according to a physical law (i.e., pressure difference in a flow direction), and the difference between the expected value versus the measured value. Definition of data validation limits for each type may be from experience, comparison to previous data, the uncertainty of the measurements, or the expected variance of top level calculated parameters.

The engine and facility operational limits must also be identified and set in BDS displays and in steady-state print pages. These limits are not generally important to data validation, but they may indicate not only where the engine or facility is beyond an operational limit, but also where the test objective and the resultant data are invalid.

3.2.6.3 Making Limits Relevant

Limits are relevant when they provide an indication of the boundaries for expected operation of a system. If the measurement systems produce data outputs which are beyond what is considered acceptable output, then the validation process will set check flags in steady data print pages, activate BDS visual alarms, and facilitate the identification of out-of-tolerance data in TIGER plots. Limits that are not set close enough to tolerance will indicate valid data when perhaps the data are invalid, so relevancy involves setting the correct type of limit which provides an indication of operation or output in an acceptable or expected range. It is past experience, previous data, and expected results that are used to set appropriate and relevant limits.

Plots of data are crucial to data validation because the entire validation set can be viewed and data beyond limits can be more easily identified. The plots will also indicate when the data validation limits can or should be modified. Plot sequences with limits should be set up prior to test.

3.2.7 Flags and Warnings

In the previous section the various data validation limits were discussed. When a limit is encountered, a notification needs to be sent for appropriate action. In this section we discuss these notifications.

3.2.7.1 Purpose of Flags and Warnings

When a validation limit is encountered, it has little impact if the limit exceedance is not visualized so that corrective action can be taken. Check flags and warnings are the notification agents for action to be taken. The purpose of data validation flags is to notify the analysis engineer that a limit has been encountered and that action is needed to verify that data are indeed invalid and to take appropriate action.

3.2.7.2 Types of Flags and Warnings

One type of data validation check flag or warning is a simple true or false for data validity. For a flag value of 1 the data have probable invalid elements, and a flag value of 0 indicates that no invalid data exist and that the data set is valid. Other check flags have a preprogrammed message which indicates the probable source of the invalid data or invalid test or test conditions. For instance, if a data validation process includes a comparison of inlet airflow measurements, the check flag or warning might include the message “Inlet airflow agreement exceeds limit by X amount.” A similar message may be communicated for any comparison of expected values or estimates with data and calculated parameters.

Other indications of invalid data are warnings that cause different colors to be displayed for invalid data. These colors are normally colored green for valid data, yellow for data near the tolerance limit, and red for invalid data beyond the yellow error band.

3.2.7.3 Display of Flags and Warnings

As was previously mentioned the check flags are displayed in the print pages. The flags are displayed on the pages near where the display of the data that were examined for validation is located. The flags display the name of the data validation subject, i.e., “Max UTR reference Temp Dist,” which indicates that the temperature measurements on the UTR reference plane are evaluated for their MDL. Other displays are for comparison of two measurements of the same physical characteristics, i.e., load cells or flowmeters. The true or false 0s and 1s indicate the satisfaction of the validation criteria or an indication of invalid data.

The data validation warning colors are displayed on the BDS screens tabular data and annunciators. Warning message colors are derived from the limits set in the IRL. In tabular displays the background of the parameter will be changed for data outside the limits. For the annunciators the background of the parameter's square on the annunciator panel will change to indicate its status.

3.2.8 Plots

Plots of data and calculated parameters have always been important to data validation and analysis. Today's platform for visualizing data plots is the TIGER system. The capability to plot steady-state and transient data with multiple plots in the same window, plots of data with different units, rapid viewing of a sequence of plots, and many other capabilities have been polished over the last 15 years in the TIGER system.

3.2.8.1 Need for Plots

Plots of data are critical to the data validation process. An isolated measurement is difficult to validate. The measurement must be compared either with an expected value of uncertainty or with another estimate. Plots of data are the primary process for final validation of the data.

3.2.8.2 Plot Types

A number of plot types are required in the data validation process. These include the difference plots of parameters (i.e. two fuel meters in a fuel flow leg), profile plots of instrument rake measurements, the plots of a parameter against a driving parameter such as speed or airflow, time trace plots of transient data for response and signal quality, plot comparisons of steady-state and transient data for transient data validation, and plots of validation parameters such as MDL. The number of plots required for data validation is the number which includes all of the data to be validated.

3.2.8.3 Independent and Dependent Parameters

In the setup, production, and viewing of plots with data, historical data, estimates, and limits, it is important to consider the independent and dependent variables in plotting data. For the engine parameters, the engine speed is the primary independent parameter. Although airflow is dependent on speed, it is sometimes considered the independent parameter. Consider a compressor map as shown in Fig. 13. The independent parameter is corrected compressor airflow, and the dependent parameter is pressure ratio. The engine operating line and stall line are plotted in terms of the independent and dependent parameters. Note also that the engine speed enters into the plot in this case as a dependent parameter of corrected airflow through the speed and airflow dependency to set the engine speed lines.

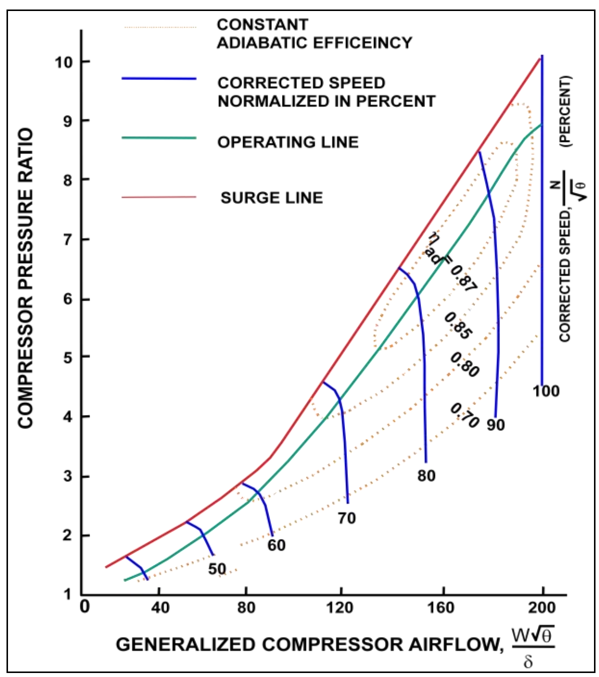

Figure 13. Typical Compressor Operating Map

Other parameters which are a function of engine inlet and exit airflows and flow properties can also be independent parameters. Engine thrust is a good example. Note that in Fig. 9 the thrust is the independent variable in the plot of TFSC versus thrust.

Other important driving parameters are associated with facility thrust, airflow and fuel flow. These independent parameters are typically associated with the ratio of similar measurements as the dependent parameter. Figure 14 shows the dependent parameter ratio of pressure transducer to the scanned average pressure with the average scanned pressure as the independent parameter. The plot with the estimated error bands and historical data is typical of ratio plots usage in data validation.

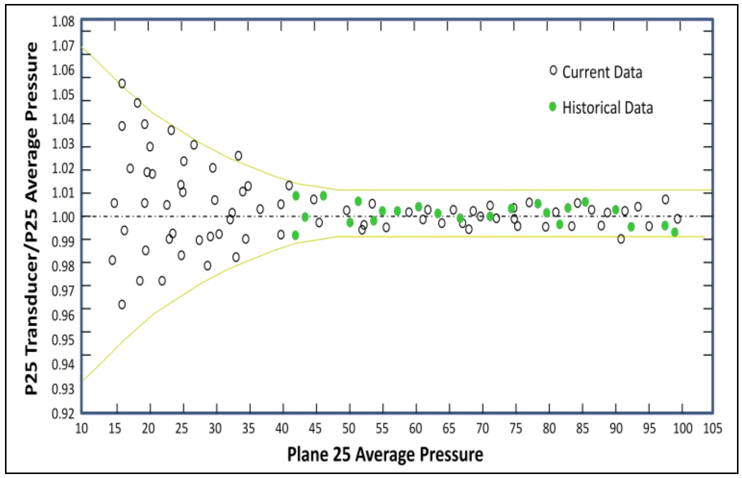

Figure 14. Transducer to Scanned Pressure Ratio

3.2.8.4 Plot Viewing Priority

Plot viewing priority depends on a number of factors, some of which are associated with the point in the test program and the test period. The most important viewing priority is for parameters and measurements for which the facility is responsible, including thrust, fuel flow, and airflow. These plots are viewed to validate the measurements which are input to the facility parameters calculation. Other plot viewing priorities are for facility measurements of the reference temperatures on the UTRs and the reference pressures of the pressure scanning system. Plot viewing priorities for engine data are dependent on the test objectives and the data supporting the test objective.

3.3 IMPLEMENTATION OF DATA VALIDATION SETUP

Setup of the test systems for data validation differs from cell to cell and from engine to engine. All tests require setup of the large BDS screens at least for engine and facility limits and the validation of fuel flows, thrust, and airflow. All tests also require the setup of print pages. For a new engine test the data validation is primarily by “eye scan” of the data in the print pages and in the BDS displays for invalid or erroneous data. This is primarily due to insufficient estimates and lack of historical data for full setup of data validation software and systems.

3.3.1 Steady-State Program Checks Using DATVAL

For repeat engine tests or for engine tests with sufficient setup time, a more extensive setup for data validation is accomplished. The data validation setup originally set forth by Patton and Chamblee has evolved to a more extensive data validation using DATVAL subroutines. These subroutines have checks and flags for the following:

- Set Conditions
- Engine and Facility Stability

- Thrust System
- Fuel System
- LP Turbine Inlet Temperature
- Control System
- Airflow
- Component Efficiency
- Multicomponent Thrust System
- Isolation Seal
- Exhaust Gas Management System for Vectoring Exhaust
- Test Cell Cooling Levels and Test Cell Pressure Gradients
- Venturi Leakage
- Temperature Measurement
- Pressure Scanning System Measurement Checks

Other data validation setup includes the calculation of measurement distortion and Max-Min limits, comparison of pressure measurements from different sources (i.e., transducer to scanned pressure value), pressure ratios and differences which must obey a physical law, and calculated or measured data limits for a dependant value and an independent driving value or function (i.e., speed). All data validation checks which are outside limits are printed on the first page of the print pages. More detailed information on DATVAL is in Appendix C

3.3.2 Data Validation Implementation with XLDV

Modern advances of spreadsheet technology with export of information capability have made the setup of plots and data validation checks in the data reduction programs a simpler process. The process is called XLDV for EXCEL™ DATA VALIDATION, indicating that the capabilities of Microsoft Excel™ are used to implement the process including the import and export capabilities and also the underlying Visual Basic programming capabilities to set up Graphical User Interfaces (GUIs). The required fields of the spreadsheet are shown in Fig. 15. These fields have all the information necessary to set up the data validation software checks in the steady-state reduction program and include the flag item number, the flag name, the segment number, the dependent parameter Y and the independent or driving parameter X, the curve-fit order values, the X and Y ranges for validation, flag type, and the tolerance levels for ambient data points. The item number identifies the data validation flag in the data reduction program. The segment numbers are different segments or ranges for validation and require separate X parameter ranges for each segment. The C0 through C6 fields are the coefficients of an up to 6th order curve to define for the data validation tolerance limits. The X and Y minimum and maximum values define the range of the X and Y values for which the validation check applies. The X value ranges are used for defining the segment ranges and for defining ranges where the dependency of Y on X is valid. For instance, a Y engine parameter dependency on speed may not be valid below engine idle, in which case the range of the X variable minimum value would be set at idle speed of the engine. The flag type identifies whether the invalid region is above or below the specified limit. The 0 value indicates that the limit line is a minimum and that the invalid region is below the limit. Likewise, a flag type of 1 indicates that the limit is a maximum and that the invalid region for data is above the specified limit. The AMB is the tolerance for ambient points, and if the field has a value, then the validation check will use the ambient tolerance.

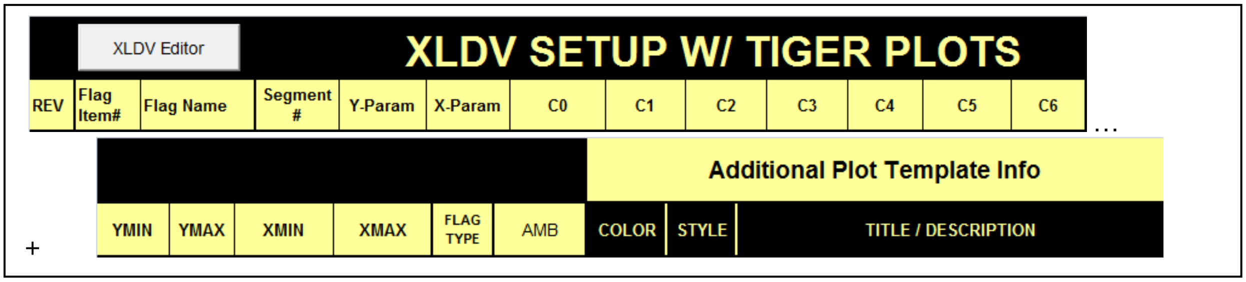

Figure 15. Fields of XLDV Spreadsheet

The row fields of the XLDV spreadsheet are exported to a flat ASCII text file. This text file is read into the memory of the computer which executes in the steady-state data reduction program. The XLDV subroutine performs the data validation checks according to the specifications of the input file. If the data are valid, the validation flag of 0 is set. If the data are invalid, a validation flag of 1 is set. The validation flag is then printed in the steady-state print pages with the appropriate validation flag description.

Macros within the spreadsheet can export files that define a TIGER plot template with background data representing each check. The macros will also produce a sequence file that groups the plot templates together.

The XLDV GUI provides a convenient form for input of check configuration data, file I/O operations and plot preview capabilities.

Although XLDV is used to date for data validation checks of data measurements, XLDV could also be used to plot performance parameters. All the fields of the spreadsheet would be the same except the driving and dependent parameters, which would be performance parameters, and the 6^{th}-order tolerance curve would be a curve describing expected or specified performance. While the plots of the top level calculated parameters could be viewed as a validation tool, the plots would also check compliance with expected values in support of the analysis of test results.

All of the data checks and plots specified by Patton, Chamblee, and Warwick and the checks of DATVAL are now incorporated in the XLDV. The automation of the data checks in the steady-state data reduction program and the automated setup of data validation plot sequences have brought a heightened level of comprehensiveness and thoroughness to the data validation process while reducing the time and effort for the data validation process setup.

3.4 DATA VALIDATION EXECUTION

The data validation execution phase consists of applying the data validation software and systems setup in the preparation phase to the online and recorded data. This phase provides valid data for online decision making and ensures that the data sent to AEDC analysts and remote customers is free of invalid date.

3.4.1 Pretest

The pretest (period of time close to the test period) activities of data validation are more intense and global for the first air period, but the basic activities are the same for any pretest. The instrumentation should be checked to ensure any last minutes changes are accounted for in data validation software and systems. This includes instrumentation additions, deletions, and modifications to patching, channel assignment, or calibrations. Ambient data points are examined for validation of check flag setup. TIGER sequence plots are stepped through to ensure that all plots are displaying the required data in the required format with background display of limits. The BDS screen layouts are reviewed for the large screens and the computer screens to ensure the correct display setup with the incorporation of any instrumentation changes. The Planning and Preparation Topics are reviewed to assure that any changes to software, expected values, instrument requirements, print pages, displays, flags, limits, and plots are captured and incorporated in the data validation systems.

3.4.2 Test Period

The test period brings to bear the focus of all of the validation systems and software to ensure that only valid data are used for online decision making and for transmittal of valid data to the AEDC analysis network and subsequently to remote customers' facilities. The intent is to ensure that the data stream is purged of invalid data. An example of a test period data verification plan is shown in Appendix D.

3.4.2.1 Determination of Invalid Data

The first line of data validation is the alarm annunciators of the EDAPS BDS screens. Whether the large screens or the workstation displays are being monitored, the warning annunciators will indicate the possibility of invalid data. At present the data validation limits for the BDS displays are constant. Therefore, further evaluation of data validity is through the print page check flags and the TIGER sequence. At present an effort is underway to incorporate nonlinear limits for the BDS displays. With nonlinear limit capability the BDS screen warnings will be more definitive in determining invalid data.

If any isolated parameters were identified in the preparation phase to have a probable correlation with other data, then the process should begin to collect the necessary data for the correlation. Data plots viewed in TIGER offer a view of the validity of the correlation and the curve fits of TIGER can be used to develop a correlation algorithm. Data may have to be collected over several air periods to establish a correlation which is valid over the required range of flight conditions and engine power settings.

The print pages are examined for each data point for invalid data indication in the validation check flags. The TIGER sequence plots are also examined to determine where any indicated invalid data lie with respect to the validation limit. If the indicated data are judged to be invalid, then the invalid data are deleted. If the limit is judged to be too restrictive, then an adjustment of the limit may be required to capture the valid data inside the limits. Although check flags and plot sequences are set up to capture the majority of the invalid data, the "eye scan" method may still be required to ascertain the validity of any excluded data.. Although transient data from pressure transducers are primarily validated against steady-state scanned pressure measurements, other TIGER plots are required of transient data to evaluate general response of the data and to note any excessive noise or drop outs.

Once the data are found to be invalid, a corrections GUI on the PDAS system network is used to apply a substitution or configure the data reduction to ignore its input. Substitutions can assign a value from other parameters or manual inputs. A discrepancy record is also entered through the EDAPS Auto-Alpha GUI to initiate actions to identify the cause of the discrepancy and to repair the discrepancy, if possible.

The checkout period and the first air period are the most intense times for data validation. The first time the engine is brought to high speed, despite the best effort at setup of the data and instrumentation systems the data from sensors may indicate patch problems, bad transducers, missing instrumentation, incorrect parameter names, bad or wrong calibration, errors in check limits, or switched data channels. Once all of the startup problems are solved, the data validation will proceed more smoothly.

3.4.2.2 Critical Validation for Objectives

Although the entire data stream is examined for invalid data during all portions of the test program, the critical data for a particular test objective will receive additional attention. First the data associated with the test objective are identified, as was discussed under the topic of Instrumentation Requirements Sheets. The data being identified will receive priority in the validation process during tests for the particular objective. Discrepancies will be identified, corrective action will be taken, and impact on objective will be assessed.

3.4.2.3 Tracking Required to Run Data

Required-to-run data are data which, if invalid, would cause the test to be stopped. From a general test operations viewpoint, required-to-run values are: speed, fuel flow, airflow, thrust, power extraction, bleed data, and reference temperatures and pressures. If errors occur in data that are required-to–run, they are identified and corrective action is taken.

3.4.2.4 Test Condition and Configuration Validation

Comparisons are generally put in place for test conditions validation. Test plans call for some conditions to be set for accomplishing test objectives. The AEDC ETF plant attempts to set required test conditions. Comparisons are made to determine the accuracy to which the conditions are set. In addition, other checks may be in place for bleed valve position, exhaust door position and temperature, thrust stand maximum temperature, fuel meter at the minimum or maximum flow, various engine and facility parameters stability, and maximum allowable test cell gradients for accurate thrust measurement.

3.4.2.5 Online Communication of Invalid Data or Test Condition

The data analyst responsible for data validation will be in constant communication with the project engineer during the test. Any questions of data validity or test condition validity will be discussed by the data analyst and the project engineer. In addition, a discrepancy entered into the EDAPS system online may prompt corrective action to repair the data discrepancy during the air period. The data analyst may also communicate with the instrument engineer or technician to relay instrumentation problems which may require online attention. The data analyst is also in communication with engine manufacturer personnel during the test to discuss possible instrumentation problems inside the engine.

3.4.3 Posttest

All discrepancies are reviewed. Any additional discrepancies are entered. Final corrections are applied to the data. Posttest fuel properties are examined and average value updates may be required. After all of the corrections are input, a decision is made as to whether reprocessing of the data is required. All of the data or only specific data points or ranges of data may require reprocessing. Any updates to systems or software are identified for incorporation into the pretest activities for the next test period.

4.0 SUMMARY AND CONCLUSIONS

AEDC’s past and present capabilities to validate data from its turbine tests have been presented and discussed. AEDC is committed to validate all data from engine tests for their intended use in engine development, validation, certification, and qualification. The advances in data validation have followed the advances in computer systems and networks, advanced data viewing and plotting systems and software, and commercially available spreadsheet software. The capabilities of the EDAPS and PDPAS systems and the TIGER graphical viewing software program have significantly improved and simplified the data validation process at AEDC.

Much of this report is devoted to the planning and preparation phase of data validation. As with any test-associated system or software, the planning and preparation phases are critical to successful validation of the data during test. The setup of systems, gathering of estimates, setting the validation priorities, assigning the applicable validation techniques, etc., are required to ensure that the data stream is fully validated.

Although the previously used data validation techniques of DATVAL and the “eye scan” method have ensured validation of engine test data, XLDV has improved and simplified the setup of data validation systems and software. It has incorporated and improved the data validation checks of DATVAL and has improved the identification of discrepancies by incorporating warnings and limit check flags into the print pages. It has also simplified and enhanced the setup of TIGER plot sequences for evaluating data. XLDV has replaced DATVAL in all test cells.

A modification to EDAPS to incorporate nonlinear limits for the data will significantly improve the validation process. The modification will effectively reproduce the same validation process that's applied to recorded data in a real time high visibility fashion. The BDS will then have the potential to become the definitive data validity indicator for analysts in the ETF.

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APPENDIX A. PATTON AND CHAMBLEE DATA CHECK PROGRAM (CIRCA 1981)

Data Validation Memo circa May 1981

To – Bill Overall, Bob Warwick, H.E. Wolf, Ed Wantland, Paul Angel, Claude Chamblee, Jack Tate

From – Wayne Patton

JTT assigned me (with assistance from Claude Chamblee) to come up with a system to minimize the amount of engineering person-hours spent checking steady-state data. The purpose is to transfer the data checking duties to the EA's or TA's and free-up the engineers for doing analysis. The attached package describes the proposed system. Please review the system & return any comments to Wayne Patton by Noon, 5-14-81.

Data Check Program

A data check program has been written which will be added to the end of the T-2 & T-4 SS Data Reduction Programs. This program checks stabilities, efficiencies, check parameter, etc. & "flags" data points which are outside normal bounds for valid data.

The purpose of the program is to identify invalid data point and data points with bad instrumentation. The purpose is not to check engine health or to catch performance shifts.

Status: The program has been checked out and run through all data in the T-2 SS File. On 30 "normal" tests we averaged less than 1 flagged Data Point/Test. On Fault Accommodation Testing, we got up to 10 flagged Data Points/Test. It is currently being added to the end of the T-2 SS program.

Major Changes between Proposed & Current System

Off-Line

Data Quality Check Plots will not routinely be made under proposed system.

Manual "eyeball" check will not be made on all data points under new system, but only on "flagged" data points.

TA or EA responsible for SS Data Quality

On-Line

1. EC4 will not check Calibrations or Pre-Test Ambient data points (Instrumentation will).

On-Line Data Checking

- For on-line Data checking the following personnel are required:
- Engineer for occasional on-line decisions (can we continue to run without a certain parameter? etc.) (Can be located in Control Room.)
- EA or TA to monitor SS Data quality.

- TA to run Dec-10 & 370 Tubes & handle on-line data.

On-Line Checking

Pre-Test Ambient & Calibrations

Suggest check by Instrumentation with verbal report of any problems to EC4. EC4 will then notify TOB rep that we are ready to run. (EC4 personnel not required to check Cals or Pre-ambient)

Pre-Test Vacuum Check

EC4 SS Monitor checks the EUD & calls the EC4 Control Room Rep in Control Room with results.

43-Type (Test) Data Points

EC4 SS Monitor checks the warning messages, EUD, and performance and notifies EC4 Control Room Rep with any problems or configuration changes (set conditions, lab seal, etc.).

Post-Test Ambient Data Points

EC4 SS Monitor checks EUD on one of the post-test ambient points. If FS is active, checks FS on all 3 post-test ambient points.

EC4 SS Monitor prepares request for SS Rerun 1 and gives 1 copy to EJ43 at end of test. (File original).

OFF-LINE DATA CHECKING

1. When 1st Rerun is printed, checker (person responsible for SS Data Quality) checks to be sure all the corrections requested on the Rerun Request were made.

Checker obtains mini-history data check program printout from subject test after RRI is printed. Makes detailed checks of flagged parameters as described in “Flag Resolution Procedure” (attached).

Rerun data as required, repeating steps 1 & 2 for each rerun.

When “Flag Resolution Procedure” is complete, checker makes up “Zap List” showing all unresolved flags, invalid data points from Project Test Log, and Data points that were not run program objective points. The data points on the “Zap List” will not be included in the final data package unless the Analysis Engineer tells the checker to put them in.

The checker gives the “Zap List” to the Analysis Engineer.

The AE returns the “Zap List” to the checker with data points marked that he wants included in the data package. (Until the EA gets confidence in the Data Check Program, he may require check plots or other aids to assure data quality.)

Data is deemed final & ready for Data Package.

NOTE- Only data points taken for run program objectives will be included in data package unless specifically requested (via the Zap List or other written means) by the analysis engineer.

User has requested (and we will comply) that the final rerun given to them (and data linked to them, if applicable) includes all valid data. I.E. they want vacuum checks, check points and other non-run-program objective points. The only things they don't want are ambient scans and invalid data points.

After the final User rerun, delete all non-data-package data points from the 370 file. This will prevent invalid and check data points from messing up subsequent plots.

Flag Resolution Procedure

If any of the Data Check Parameters are non-zero, take the action specified.

Stabilities

The program checks the instability [(max-min)/arrange] of the following parameters

PSOO	WFT	N2	FSB
PCELL	NI	FSA	PS2P

If the flag (parameter name KKSTBxxxx) is non-zero, it represents the stability of the parameter and denotes the stability was outside present limits.

Action: Check the scans of the unstable parameter, looking for obviously bad scans. If any of the scans are obviously bad, delete them and rerun the data point. If not, put the Data Point on the Zap List*.

*Zap List- A list of Data Points and Flag Values that are outside normal tolerances but on which no bad instrumentation is obvious. The checker is telling the Analysis Engineer "These data points are abnormal and I can't figure out why. Unless you tell me differently, I'm going to delete them from the data package and SS file."

FUELCK

The program checks the 2 Facility flow meters in use to see if their ratio is outside normal limits. If KKFUELCK is non-zero, it represents this ratio and denotes that the ratio is outside normal limits.

Action: Look at the 2 flow meters in use, along with the next higher range meters, WFGG and the on-line discrepancy record to try to determine which meter is wrong. If you can, delete the meter and rerun the point. If you can't, add to the Zap List.

WFPWCK

The program checks the Facility vs. the User (WFGO) flow meters to see if their ratio is outside normal limits. If KKWFPWCK is non-zero, it represents this ratio and signifies the ratio was outside normal limits.

Action: Same as FUELCK.

DELTFE

The program checks the ΔT between the 2 thermocouples used to measure fuel temperature at the Facility Flow meters. If KKDELTFE is equal to 999, it denotes the ΔT was either exactly zero or greater than a preset limit.

Action: Look at DELTFE in the dump (Item # 2363). If it is 0, this probably means both TFE's have been zeroed out. Check to insure that SPGR (Item #1646) has not been calculated using TFE-0. If DELTFE is not 0, this indicates the ΔT between the 2 thermocouples is outside the normal range. Look at the 2 thermocouples used, the thermocouples on the higher range flow meters, previous data points, and the on-line discrepancy record to try to determine which thermocouple is wrong. If you can determine this, check to see which one was used to calculate SPGR (only uses 1 T/C). If the good one was used, forge on. If the bad one was used, substitute the good one for the bad one and rerun the data point. If DELTFE is not 0 and you can't decide which one is bad, add to the zap list.

FSCHECK

The program checks the ratio of FSA & FSB. If KKFSCHECK is non-zero, it represents this ratio and indicates the ratio was outside the normal band.

Action: Look at FSA and FSB with past data and math model and discrepancy record, if you can determine which is bad. If you can, zero it and rerun the point. If you can't, add it to the zap list.

WABME

The program calculates the ratio of WA2 (usually venturi if installed) to the inlet duct airflow (WABME or WAIM in T-4 and T-2 respectively). IF the flag (KKWABME) is non-zero, it equals this ratio and indicates the ratio was outside the normal band.

Action: Look at WA2 vs. the inlet duct airflow (WABME or WAIM) and see if you can decide which one is wrong by using previous data, math model data, etc. Do NOT check against WAZM, as it has parameters in common with WABME & WAIM and the same bad parameter could affect all 3 of them. If one is obviously wrong, check the EUD parameters that go into it (shown below). If you can't decide which one is wrong, check the EUD parameters going into both airflows.

WA2	WAIM(T2)	WABME(T4)
PSOO's	PSI's	PSBME's
PSIN's	PS2P's	PS2P's
TOO's	T2P's	T2P's

If you find any bad EUD values, zero and rerun the data points. If you don't, add to the Zap List.

PAB

The program checks the relationship between PGM and PAB. If the flag is non-zero, it implies that their relationship is outside the normal band. If KKPAB is positive, it means PAB is too high relative to PGM. If KKPAB is negative, it means PAB is too low relative to PGM.

Action: Look at previous data, math model, discrepancy record, etc. to see if you can decide which one is bad. If you can, delete the bad one and rerun the data. If you can't, add to Zap List.

CV3

The program calculates the nozzle velocity coefficient. If the flag is non-zero, it implies that CV3 is outside the normal range and the flag (KKCV3) gives the value of CV3.

Action: Check the EUD and input parameters listed below.

MOD	PGC's	TGC's
FS's	PGH's	TGH's

If bad EUD values are found, zero and rerun the data point. Otherwise, add to Zap List.

Lab Seal

The program calculates the ΔP between the upstream and downstream portions of the lab seal. If the flag (KKLSEAL) is non-zero, it implies that the ΔP is outside the normal range and the flag gives the value of the ΔP.

Action: Check the PSLSU's and PSLSD's for obviously bad EUD values. If you find any, zero and rerun the data. If you don't find any, add to the Zap List.

P2 Set Conditions

The program calculates the ΔP between P2 desired and P2 actual. If the ΔP is outside the allowable band, it checks to see if we were setting any of the following "quasi-sea-level-static" conditions.

P2/PSO = 14/14, 12/12, 10/10, 12/10, 12/8

If none of the above were set and the ΔP was outside the band, a non-zero value will be assigned to the flag (KKP2D) and its value will represent the ΔP.

Action: Check the P.E. log to see if P2D is set correctly in the program. If not, change it and rerun the point. If it is, check the EUD values of P2. (Normally the PS2P's) If any are obviously bad, delete and rerun. Otherwise, add to Zap List.

PSO Set Conditions

The program calculates the ΔP between PSO desired and PSO actual. The same checks are made on PSO as are described in the P2 section above. If KKPOD is non-zero, it indicates that the ΔP was outside the allowable band, and the flag gives the ΔP value.

Action: Same as P2 action except check the EUD values of PCELL.

T2 Set Conditions

The program calculates the ∆P between T2 desired and T2 actual. If the flag (KKT2D) is non-zero, it indicates that the ∆T is outside the allowable band and the flag gives the value of the ∆T.

Action: Check the P.E. Log to see if T2D is set correctly in the program. If not, change it and rerun the point. IF T2D is ok, check the T2P's to see if we have any bad instrumentation. (Caution: On cold or hot T2's, a large profile is frequently seen – this is not bad instrumentation. If in doubt, ask your analysis engineer.) If you find a bad T2P, zero and rerun the data. Otherwise, add to Zap List.

Ram Ratio Check

The program divides the desired ram ratio by the actual ram ratio to obtain a "ram-ratio ratio". If this ratio is outside the allowable band and the exhaust nozzle is un-choked, we cannot correct the performance data on that data point. If this happens, the program sets KKRAMRAT equal to the "ram-ratio ratio". Otherwise KKRAMRAT=0.

Action: Check the KKP2D and KKP0D flags. If either of these were non-zero, this problem has already been addressed. If the data point has been added to the Zap List, add KKRAMRAT to the Zap List. If a problem was found in the KKP2D or KKPOD section, ignore this flag. The corrective action for the earlier flag should also correct this one. If, however neither the KKP2D nor the KKPOD flag came up on this data point, check all of the parameters listed below.

P2D	PS2P's
POD	PCELL's

If any of the above is wrong, fix and rerun the data. Otherwise, add the data point to the Zap List.

T45

The program calculates a Station 45 temperature from several measured parameters and divides it by the measured station 45 temperature (FTIT). If this ratio is inside the normal band, KKT45XQI = 0.0. Otherwise, KKT45XQI is set equal to this ratio.

Action: Check the following parameters for bad instrumentation.

T3H's	T25H's	WFTL's, M's, or H's (whichever is in use)
P3H's	P25H's	TFEL's, M's, or H's (whichever is in use)
		WFGG

If any of the above EUD parameters are bad, zero and rerun the data. Otherwise, add to the Zap List.

Efficiencies

Several component efficiencies are calculated in the Steady-State program. The check program checks the major efficiencies to insure that they are within normal bands. If an efficiency is within its band, the flag associated with that parameter will be set equal to 0.0. Otherwise the flag will be set equal to the efficiency.

Action: Check the EUD valves of the parameters from which each efficiency is calculated (shown below). If no bad EUD values are found, add the parameter to the Zap List. If bad EUD valves are found, zero and rerun the data point.

Fan Inner Diameter

Flag = KKETAFID

Parameters to check: T2P's PS2P's T25H's P25H's

Fan Outer Diameter

Flag = KKETAFOD

Parameters to check: T2P's PS2P's T25C's P25C's

Fan Average

Flag = KKETAFAV

Parameters to Check: T2P's T25C's T25H's

PS2P's P25C's P25H's

High Pressure Compressor

Flag = KKETAHPC

Parameters to Check = T25H's T3H's

P25H's P3H's

Overall Turbine

Flag = KKETATURB

Parameters to check: T3H PGM WFEL's, M's or H's

P3H TFEL's, M's or H's

Augmenter

Flag = KKETAAB2

Parameters to Check =	MOD (vs. P.E. Log)	T25C's	TGC's	PCELL
	T2P's	P25C's	TGH's	WFEL's, M's, or H's
	PS2P's	T3H's	PGM	TFEL's, M's, or H's

APPENDIX B. DATA VALIDATION PRESENTATION BY BOB WARWICK (CIRCA 1986)

OUTLINE

- WHAT IS DATA VALIDATION?
- WHAT INFORMATION DO WE NEED TO VALIDATE DATA?
- WHERE DO WE GET ESTIMATES?
- WHAT DO WE VALIDATE?
- HOW DO WE VALIDATE DATA?
- PRIORITIES IN DATA VALIDATION
- SIGNAL QUALITY CHECKS
- FACILITY VALIDATION METHODS
- ENGINE VALIDATION METHODS
- ENGINEERING DATA MEASUREMENT CHECKS
- PERFORMANCE CALCULATIONS
- ENGINE COMPONENT PERFORMANCE
- RECOMMENDED COMPONENT PLOTS
- CAUTIONS
- SUMMARY

WHAT IS DATA VALIDATION?

DATA VALIDATION ANSWERS THE QUESTIONS:

- IS THE DATA OF GOOD ENOUGH QUALITY TO USE FOR THE CONTRACTUAL PERFORMANCE GUARANTEES?
- SHOULD THE DATA POINT BE THROWN AWAY?
- SHOULD THE DATA POINT BE KEPT AND USED FOR ONLY CERTAIN TASKS (EXCLUDING CONTRACTUAL GUARANTEES)?
- WHAT IS WRONG WITH THE DATA AND CAN IT BE FIXED?
- HOW CAN IT BE FIXED, AND IS IT WORTH THE EFFORT?

NOTE: THIS PRESENTATION ASSUMES THAT THE COMPUTER DATA PROGRAM HAS ALREADY BEEN CHECKED OUT/VALIDATED

WHAT INFORMATION DO WE NEED TO VALIDATE DATA?

WE MUST HAVE ESTIMATES OF WHAT TO EXPECT FOR ALL OUR CHECKS, SUCH AS

- ENGINE THRUST
- ENGINE FUEL FLOW
- ENGINE COMPONENT PERFORMANCE
- FACILITY CAPABILITIES/LIMITS/STABILITY
- ENGINE/CONTROL SYSTEM LOGIC/LIMITS/STABILITY
- ACCURACY/UNCERTAINTY OF MEASUREMENTS

WHERE DO WE GET OUR ESTIMATES?

- COMPUTER MATH MODEL
- ENGINE SPECIFICATION (CONTRACT GUARANTEES/ESTIMATES)
- DATA FROM ANOTHER ENGINE OF SAME MODEL
- MANUFACTURER'S SEA LEVEL CHECKOUT OF THAT ENGINE
- DATA FROM PREVIOUS TEST OF SAME ENGINE AT OTHER FLIGHT CONDITIONS (GENERALIZE/NORMALIZE)
- THEORETICAL ESTIMATES
- PREDICTIONS BASED ON OTHER ENGINE/COMPONENT TESTS (NOT YET PUT IN MATH MODEL)
- INSTRUMENT MANUFACTURER'S ACCURACY ESTIMATES
- KNOWLEDGE OF TEST FACILITY AND ENGINE CAPABILITIES, LIMITS, STABILITY
- TEST EXPERIENCE WITH INSTRUMENTS/SENSORS
- DATA BANK/EXPERIENCE

WHAT DO WE VALIDATE?

EVERYTHING

- ALL INSTALLATIONS DIMENSIONS –
  - INLET DUCT DIAMETER AT LABYRINTH SEAL
  - VENTURI AND/OR INLET DUCT THROAT AREA FOR AIRFLOW
  - MEASUREMENT/CHECKS
  - LOCATION OF INSTRUMENTATION
  - ENGINE GEOMETRY SUCH AS EXHAUST NOZZLE AREA
- SIGNAL QUALITY OF DATA
- ALL DATA MEASUREMENTS – P, T, WF, FS - - - - -
- ALL CALCULATED VALUES
- FACULITY
  - STABILITY
  - TEST CONDITIONS
- ENGINE
  - STABILITY
  - OPERATION
  - LOADING

HOW DO WE VALIDATE?

- COMPUTER AUTOMATIC PROGRAMMED CHECKS OF
  - SPECIFIED LIMITS OR RANGES
  - COMPARISONS OF DUPLICATE MEASUREMENTS (Computer Will Flag or Write Error Message)
- COMPUTER STATISTICAL CHECKS OF
  - PROFILES – SPECIFY BAD PARAMETER
  - SIGNAL QUALITY (Computer Can Delete if Option Selected, Fill Routines are Available)
- MACHINE PLOTS/COMPARISON OF OVERALL/COMPONENT PERFORMANCE
  - MANUAL COMPARISON OF TEST DATA WITH
    - MATH MODEL ESTIMATES

  - PREVIOUS TEST DATA (normalized)
  - OTHER
- MACHINE PLOTS OF PROFILES
  - MANUAL COMPARISON OF PROFILES
- SUMMARIZED PRINTS OF CHECK VALUES WITH FLAGS
  - COMPUTER PRINT – MANUAL SCAN

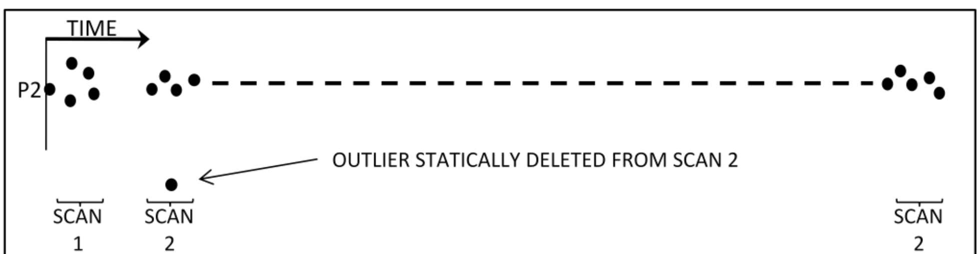
PRIORITIES IN DATA VALIDATION

- SIGNAL QUALITY (Electrical Noise/Computer/System Error)
- STABILITY – ARE THE FACILITY AND ENGINE WITHIN ACCEPTABLE STABILITY [(Max-Min)/Avg] LIMITS DURING THE ACQUISITION OF THE DATA POINT?
- FACILITY
  - CORRECT SET CONDITIONS
  - ENGINE INLET PRESSURE, P2
  - ENGINE INLET TEMPERATURE, T2
  - TEST CELL PRESSURE
  - FUEL SUPPLY PRESSURE, TEMPERATURE (Within Limits)
- ENGINE
  - CORRECT LOADS
  - SHAFT POWER EXTRACTION
  - COMPRESSOR BLEED AIR
  - CORRECT TRIM SETTING (Is Engine/Control System Correctly Adjusted?)
    - POWER LEVER POSITION
    - VARIABLE GEOMETRY
      - EXHAUST NOZZLE AREA
      - COMPRESSOR GUIDE VANES POSITION
- MEASUREMENTS
- CALCULATIONS

SIGNAL QUALITY CHECKS

DATA SYSTEM CHARACTERISTICS

- TIME-SHARED SYSTEMS



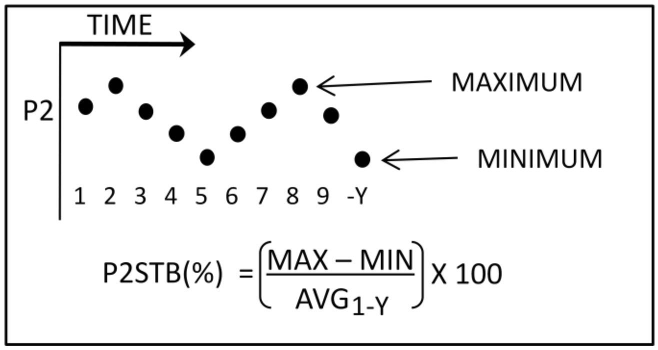
$$P2(AVERAGE) = \frac{\left[\frac{\sum \text{ of X RECORDS SCAN 1}}{X} + \frac{\sum \text{ of RECORDS SCAN 2}}{X} + \frac{\sum \text{ of X RECORDS SCAN Y}}{X}\right]}{Y}$$

- STATISTICAL ROUTINES MAY BE APPLIED TO DELETE OUTLIERS FROM EACH OF THE Y SCANS
- EACH SCAN MAY OR MAY NOT BE CONNECTED TO A DIFFERENT PRESSURE SENSOR

FACILITY VALIDATION METHODS

ENGINE INLET P2 AND T2, CELL PSO, FUEL PF AND TF

- CAL STABILITY FOR Y MEASUREMENTS PER DATA POINT(Limited to Those Parameters Measured Repetitively on all Y Scans)

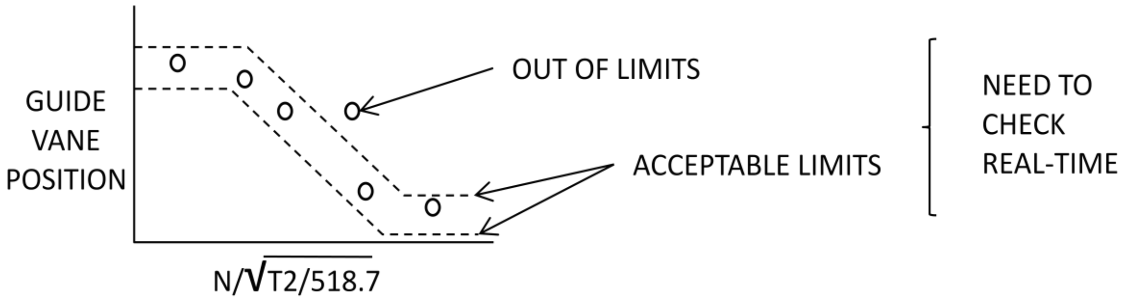


- TEST: IF P2STB > P2STBLIM (Acceptable Limit)
  IF NO – PRINT NO MESSAGE
  IF YES – PRINT “P2STB EXCEEDS LIMIT = XX.XX”
- OR PRINT P2STB = XX.XX AND * IF > P2STBLIM REPEAT FOR T2, PSO, PF, TF –
- COMPARE TO DESIRED SET CONDITIONS
- CALC/P2 – P2DES/ OR P2/P2DES AND COMPARE TOACCEPTABLE LIMIT, IF OUT OF LIMITS PRINT “P2 OUT OFLIMITS”
- REPEAT FOR T2, PSO, PF, TF
- CAN ALSO TABULATE OR PLOT VALUES FOR EACH POINTAND MANUALLY CHECK

ENGINE VALIDATION METHODS

- LOADS
  - CHECK POWER EXTRACTION AND BLEED
    - STABILITY – CHECK WITH COMPUTER LIKE P2
    - CHECK LEVEL WITH COMPUTER OR MANUALLY
- CORRECT TRIM SETTINGS

	STABILITY	LEVEL
○ POWER LEVER POSITION	X	
○ ROTOR SPEED	X	
○ FUEL FLOW	X	
○ VARIABLE GEOMETRY		
▪ EXHAUST NOZZLE	X	SCHEDULE/LIMITS
▪ COMPRESSOR GUIDE VANES	X	SCHEDULE/LIMITS

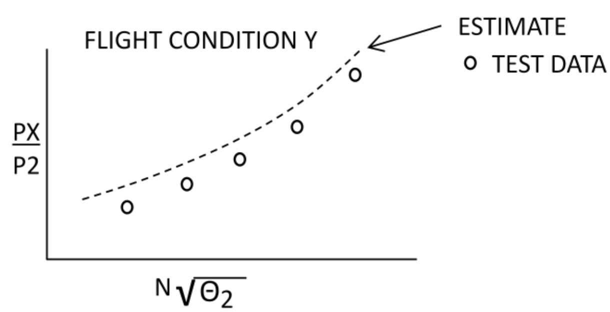


- CAN CHECK GUIDE VANES BY –
  - PROGRAMMING COMPUTER TO PRINT ERROR MESSAGE
  - REAL-TIME PLOTTER IN CONTROL ROOM
  - MANUAL PLOT-ON LINE

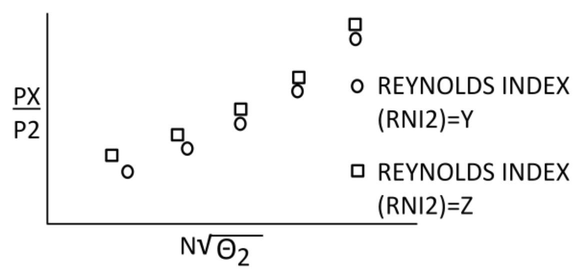
ENGINEERING DATA MEASUREMENT CHECKS

AERODYNAMIC PRESSURES AND TEMPERATURES

- PROFILES
  - STATISTICALLY CHECK/DELETE
  - MANUALLY CHECK COMPUTER PLOTS
  - COMPARE TO PREVIOUS DATA
  - WATCH T/C'S – MOST FREQUENT PROBLEM
- COMMON SENSE
  - PT AND TT CANNOT INCREASE AS AIR FLOWS THROUGH PIPE UNLESS HEAT/WORK ADDED
  - PS DECREASES WITH INCREASING VELOCITY
- COMPARE TO EXTIMATES/OTHER DATA



FOR ANY ENGINE



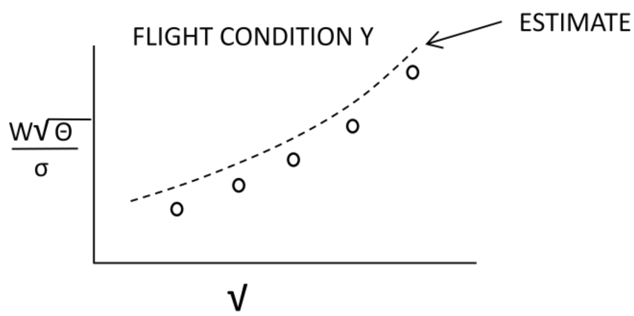
FOR LOW BYPASS ENGINES WITH CHOKED EXHAUST NOZZLE AND CONSTANT NOZZXLE AREA OF SIMILAR NOZZLE AREA SCHEDULES

- FUEL FLOW (WF)
  - COMPUTER CHECK DUPLICATE METERS AGAINST EACH OTHER
  - COMPUTER CHECK WF STABILITY
  - COMPUTER CHECK FUEL METER TEMP, AGAINST ANOTHER
  - INDEPENTENT FUEL TEMP. (Other Meter or Supply TF)
  - MANUALLY CHECK FUEL ANALYSIS SPECIFIC GRAVITY, HEATING VALUE,

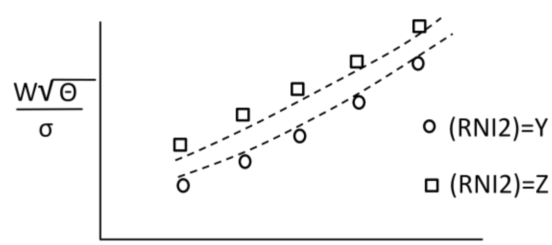
- VISCOSITY INPUTS
- COMPARE TO ESTIMATES/OTHER DATA
- THRUST (Load Cell-FS)
  - COMPUTER CHECK DUAL BRIDGES AGAINST EACH OTHER
  - COMPUTER CHECK FS STABILITY
  - COMPUTER OR MANUALLY CHECK LOAD CELL/THRUST STAND
  - ENVIRONMENTAL TEMPERATURES
  - CAREFULLY OBSERVE THRUST SYSTEM TARE CHECKS AND
  - CALIBRATION
  - WATCH FOR THRUST SYSTEM ZERO SHIFTS
  - COMPARE TO ESTIMATES/OTHER DATA (See calculations)

PERFORMANCE CALCULATIONS

- AIRFLOW
  - COMPARE DUPLICATE MEASUREMENTS (Venturis vs Inlet Duct)
  - WATCH FOR LABYRINTH SEAL LEAKAGE AFFECTS
  - CHECK STABILITY/LEVELS/PROFILES OF ALL INPUTS TO CALC
    - CALCULATE/COMPARE AIRFLOW UPSTREAM vs DOWNSTREAM OF
    - LAB. SEAL
    - COMPUTER CHECK/FLAG LAB. SEAL UNBALANCE
  - CHECK AGAINST ESTIMATES/OTHER DATA

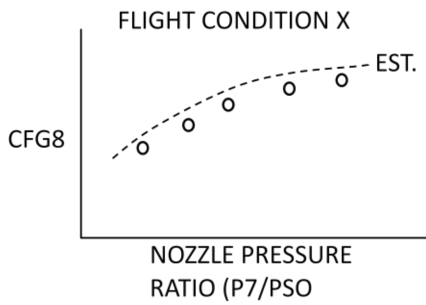


FOR ANY ENGINE

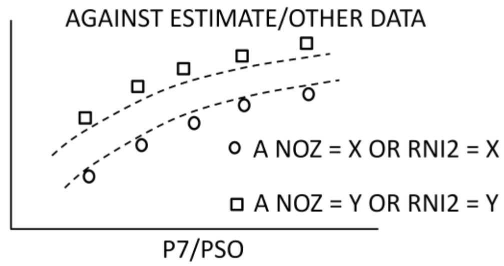


FOR LOW BYPASS ENGINES WITH CHOKED EXHAUST NOZZLE AND CONSTANT NOZZXLE AREA OF SIMILAR NOZZLE AREA SCHEDULES

- THRUST
  - COMPARE THRUST COEFFICIENT (CFG9 = FGS/FGI)

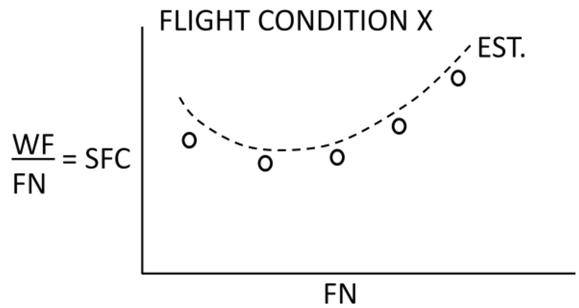


OR



PERFORMANCE CALCULATIONS (CONCLUDED)

- THRUST SPECIFIC FUEL CONSUMPTION

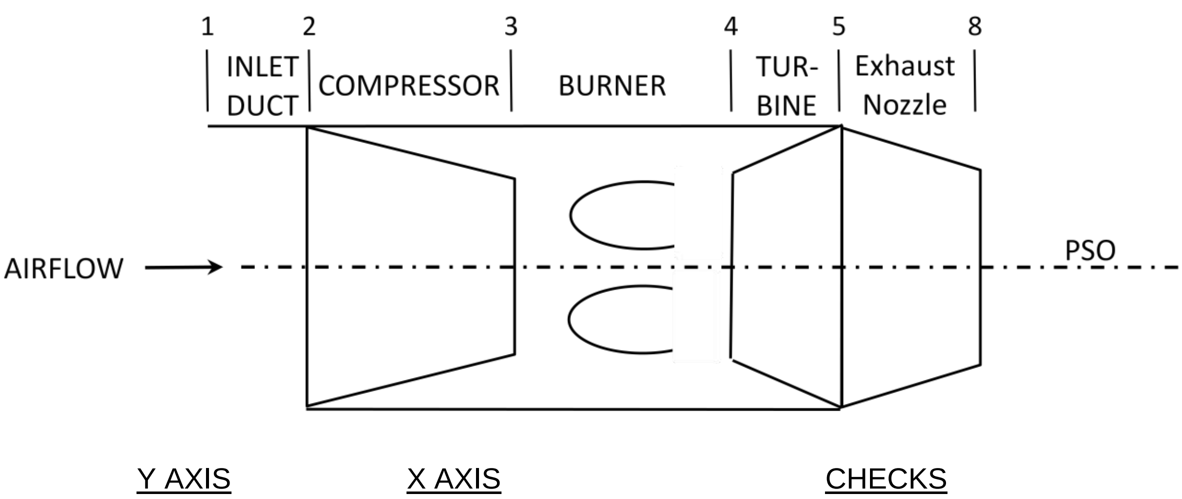


THIS PLOT CHECKS THRUST, FUEL FLOW, AIRFLOW

ENGINE COMPONENT PERFORMANCE

- CHECK ALL AGAINST ESTIMATES/OTHER DATA
    - PROVIDES INDICATION OF INCONSISTENT DATAMEASUREMENTS AND CALCULATION ERRORS
    - PROVIDES INDICATION OF SIGNIFICANT MEASUREMENT BIASESAND CALCULATION ERRORS
    - DOES NOT HELP FIND SMALL MEASUREMENT BIASES OR SMALLCALCULATION ERRORS

RECOMMENDED COMPONENT PLOTS/CHECKS vs ESTIMATES



	Y AXIS	X AXIS	CHECKS
1.	WA2√θ2/σ2	N/√θ2	*WA, T2, P2, N
2.	COMP. EFF.	N/√θ2	P2, T2, P3, T3
3.	P3/P2	WA2√θ2/σ2	P3, P2, T2, WA2, (Operating Line)
4.	WF/(σ2 x √θ2)	N/√θ2	WF, P2, T2, N
5.	TURBINE EFF.	P4/P5	P4, P5, Y4, T5
6.	CFG9	P8/PSO	*P8, T8, PSO, WA, P1, PSI, A1, FS

*ALREADY COVERED UNDER AIRFLOW AND THRUST CALCULATIONS

CAUTIONS

- MUST KEEP LOG OF ENGINE/FACILITY HARDWARE CHANGES
- MUST KEEP LOG OF INSTRUMENTATION CHANGES
- A GOOD CONTROL ROOM TEST LOG OF EVENTS, RUN PROGRAM CHANGES, AND ANOMALIES CAN SAVE EXTENSIVE DATA CHECKING TIME
- MAKE UP A ROUTINE LIST OF CHECK PLOTS THAT CAN BE PRODUCED BY COMPUTER AFTER EACH TEST PERIOD
- USE COMPUTER TO VALIDATE DATA DURING TEST (Engine Must Be Operating properly, Loaded Correctly, and Facility Conditions Must Be Acceptable)
- THE LARGE ERRORS ARE EASY TO FIND; THE SMALL ERRORS (<2%) CAN BE MUCH HARDER

SUMMARY

- PLAN/PROGRAM YOUR DATA VALIDATION PROCEDURES BEFORE THE TEST PROGRAM BEGINS
- OBTAIN AS MANY ESTIMATES AND AS MUCH DATA AS POSSIBLE FOR COMPARISON BEFORE THE TEST STARTS
- LET THE COMPUTER DO MOST OF THE ROUTINE WORK
- IF YOU FIND A DATA PROBLEM
- CHECK THE CONTROL ROOM LOG
- LOOK AT THE ERROR MESSAGES/FLAGS
- LOOK AT YOUR AUTOMATED CHECK PLOTS
- IF THESE ACTIONS PROVIDE NO CLUES TO THE CAUSE OF THE
- PROBLEM, DRAW UP A PLAN OF ATTACK, AND CHARGE IN

COMPUTER CHECKS RECOMMENDED FOR FACILITY STANDARD

- SET CONDITIONS
  - P2 VS P2D
  - PAMB VS PAMBD
  - T2 VS T2D
  - P2/PAMB VS (P2/AMB)D
  - PAMB VS P2 (CHECK NEGATIVE RAM)
  - TPLMAX VS TPLMIN (PLENUM TEMP PROFILE)
  - PAMBMAX VS PAMBMIN (SS SPREAD OF PAMB)
  - PAMB (DED) VS PAMBAVG (AMPSS)
  - PSPLMAX VS PSPLMIN (SS SPREAD OF PSPL OR P2)
  - PSPL (DED) VS PSPLAVG (PSPL OR P2 DED XDUCER VS AVG)
  - TPL VS T2 (TPL VS T2 AGREEMENT)
- LAB SEAL
  - BALANCE (V.S. AVG D.S. AVG)
  - CIRCUMFERENTIAL PROFILE – UPSTREAM
  - CIRCUMFERENTIAL PROFILE – DOWNSTREAM
  - MANIFOLD PRESSURE VS ARITHMETIC AVG – UPSTREAM
  - MANIFOLD PRESSURE VS ARITHMETIC AVG – DOWNSTREAM
- THRUST SYSTEM
  - FS1 VS FS2 (BRIDGE AGREEMENT)
  - TLC1 VS TLC2 (LOAD CELL ΔT)
  - TLCC1 VS TLCC2 (LOAD CELL COLUMN ΔT)
  - TMSCMAX VS TMSCMIN (MODEL SUPPORT CAR TEMP SPREAD)
  - FSAVG VS CAL RANGE (FS MEASUREMENT VS CAL. RANGE)

  - CFGMEAS VS CFGPRED (MEASURED VS PREDICTED THRUST COEFFICIENT)
  - P7/PAMB VS (P7/PAM) OR (EXHAUST NOZZLE CHOCKED)
  - FS ADJUSTED FOR 7TH STAGE BLEED
  - FA ADJUSTED FOR 13TH STAGE BLEED
  - FS ADJUSTED FOR FAN STAGE BLEED
  - FS ADJUSTED FOR ZERO SHIFT
  - EXHAUST NOZZLE DIVERGENT FLAP MODE
  - CD8MEAS VS CD8PRED (MEASURED VS PREDICTED EXHAUST NOZZLE FLOW COEFFICIENT)
  - CAL LOAD CELL = 0.0
- FUEL SYSTEM
  - WFT1 VS WFT2 (SELECTED FLOW METER AGREEMENT)
  - TF1 VS TF2 (FUEL METER TEMP AGREEMENT)
  - TF VS TF0 (FUEL METER TEMP VS TF0)
  - WFT VS WFGG (FACILITY VS ENGINE FUEL FLOW AGREEMENT)
  - FMX VS RNG (SELECTED FUEL METER WITHIN VALID MEASUREMENT RANGE)
  - FMX VS FCODE (FLOW METER SELECTION CODE IS CORRECT; i. e., NEXT LOWER RNG METER READING APPROX. 0.0)
  - WFAB VS WFABX (FACILITY A/B FUEL FLOW VS SPRAY RING CALC)
- AIRFLOW SYSTEM
  - PSV/PV VS PSV/PV CRT (VENTURI CHOKED)*
  - WBM VS WV (BELLMOUTH VS VENTURI WA AGREEMENT)
  - WSLS VS WA2 (LAB SEAL WA VS WA2 (METHOD SELECTED))
  - W2 VS WA2 (WA DOWNSTREAM OF LAB SEAL VS WA2)
  - WA2CM VS WA2CP (WA2C MEASURED VS WA2C PREDICTED FROM WA2C VS PV/P2 CURVE)
  - VENTURI OPEN OR CLOSED*
  - VENTURI INLET TEMP INVALID*
- ICING CHECKS
  - PSLS VS PAMB AND T2 VS 32OF (POTENTIAL FOR ICING IF AMBIENT TEST CELL
  - COOLING AIR USED)
  - T2 VS TDEWPT (T2 VS DEW PT FROM HYGROMETER)
  - DPSCR VS WA2C2 (FOD SCREEN ΔP/PSPL VS WA2C2 – HELPS DEFINE CRT ALARM
  - LINE)
- ENGINE/FACILITY/DATA SYSTEM STABILITY
  - STBPSPL
  - STBPAMB
  - STBTPL
  - STBPV
  - STBN1
  - STBN2
  - STBPLA
  - STBWFX1
  - STBWFX2
  - STBFS1
  - STBFS2

*THESE CHECKS MAY INVOLVE MORE THAN ONE.

APPENDIX C. DATA VALIDATION USING DATVAL

Volume 2

AEDC TURBINE ENGINE
DATA VALIDATION HANDBOOK

Computer Software Documentation

CONTENTS

Appendices NOT included

1.0 DATVAL SOFTWARE DESCRIPTION

The data validity software package consists of two primary subprograms (subroutines DATVAL and SETUP) and one secondary (or utility) subprogram (subroutine STBCK). A description of these subprograms follows.

1.1 Subroutine DATVAL

This subprogram is a standardized, pre-programmed module which contains all data validity checks and warning messages. These checks have been functionally grouped into the following categories:

1. **Set Conditions** - differences between as-tested and desired engine inlet and test cell conditions are calculated and compared to specified tolerances. Additional checks are included to detect the potential for icing conditions to exist in the facility/engine inlet system.

2. **Stability Checks** - the stability of selected parameters sampled periodically during a data point are calculated and compared to specified tolerances.

3. **Lab Seal Checks** - lab seal pressure balance and lab seal instrumentation checks are made to ensure accurate determination of engine thrust and airflow.

4. **Thrust System Checks** - load cell outputs are checked versus calibration range, and bridge agreement is compared to specified tolerances. Additional validity checks are included to determine if (a) load cell output is being adjusted for zero shift or overboard engine bleeds, (b) exhaust nozzle is unchoked, (c) agreement between calculated and predicted exhaust nozzle coefficients is within specified tolerances, and (d) thrust system hardware temperature profiles are within specified limits

5. **Fuel System Checks** - proper facility flowmeter range selection is verified. Agreements between (a) redundant facility flow meters, (b) redundant engine flow meters, and (c) facility and engine flow meters are compared to specified tolerances. Fuel temperatures used in fuel flow calculations are checked for validity.

6. **LP Turbine Inlet Temperature Checks** - temperature spreads (max-min, max-avg, avg-min) are compared to specified limits. Agreements between electrical harness average and arithmetic average temperature, and between calculated and measured temperature, are compared to specified tolerances. Comparison is also made to LP turbine inlet temperature limits.

7. **Control System Checks** - variable geometry tracking (fan and HP compressor inlet guide vane position) is compared with engine control schedules. Additional checks are included to ensure proper control system operation.

8. **Airflow Checks** - redundant calculations of engine inlet airflow are checked for agreement within specified tolerances to ensure accurate airflow determination.

9. **Component Efficiency Checks** - calculated versus predicted values of selected engine component efficiencies are checked for agreement within specified tolerances to ensure engine health and/or instrumentation integrity.

10. **Multi-component Thrust System Checks** - vertical load cell outputs are checked versus calibration range, bridge disagreement is compared to specified tolerances, the delta between effective and geometric vector angles is compared to a specified tolerance, and the delta between demanded and geometric nozzle vector angle is compared to specified tolerances.

11. **Isolation Seal Checks** - checks for isolation seal contact, variation in isolation seal total pressure loss from expected value, and variation in calculated isolation seal flow coefficient from expected level to ensure accurate determination of engine thrust.

12. **Exhaust Gas Management System for Vectoring Exhaust Nozzle** - checks closure door positions versus calibration range and checks redundant closure door position indicators against a specified tolerance, checks for consistent and appropriate closure door and test cell temperatures to ensure safe operation.

13. **Test Cell Cooling Levels and Test Cell Pressure Gradients** - checks to ensure test cell cooling levels and test cell pressure gradients do not exceed specified levels to ensure accurate thrust measurement.

14. **Venturi Leak Checks** - checks for venturi seal leaks using venturi vacuum pump system to ensure accurate airflow measurement.

15. **Temperature Measurement Checks** - checks reference and verification temperatures to ensure accurate temperature measurements.

16. **Aerodynamic Pressure Measurement Checks** - checks APMS floating, vacuum, and ambient reference pressures to ensure accurate pressure measurements.

Required inputs to subroutine DATVAL are specified in a user-provided subprogram (subroutine SETUP). These inputs are transferred to subroutine DATVAL via standardized common blocks (similar to TETAS). A warning flag is set, and a standardized warning message is generated for display on the data point printout for each validity check not satisfied in DATVAL. Outputs from DATVAL are transferred to subroutine SETUP via standardized common blocks.

A listing of subroutine DATVAL is found in Appendix A (not included). A summary of warning messages contained in DATVAL is found in Appendix B (not included). A description of the constants, inputs, outputs, and warning flags contained in DATVAL can be found in the nomenclature section.

1.2 Subroutine SETUP

This subprogram is a user-provided module which initializes constants and inputs to subroutine DATVAL, calls DATVAL, and stores outputs from DATVAL into the test data array.

Constants (data check tolerances, limits, etc.) which have been originally stored in the test data array are loaded into standardized common blocks using DO loops and equivalence statements (in a manner similar to that followed in TETAS). Inputs to DATVAL are then specified by the user (calculations, program item numbers, etc.) by parameter name (see nomenclature). Subroutine DATVAL is then called. Outputs from DATVAL (contained in standardized common blocks) are subsequently stored into the test data array again using a combination of DO loops and equivalence statements.

1.3 Subroutine STBCK

This subprogram is a utility routine which performs repetitive calculations found in DATVAL. Its primary use is for determining parameter stabilities during a steady-state data point. A listing of subroutine STBCK is found in Appendix C (not included).

A flow chart for automated checking of steady-state data utilizing this software package is provided on the following page. (not included)

2.0 DATAVAL NOMENCLATRUE

DATVAL CONSTANTS

PARAMETER	DESCRIPTION
P2TOL	DESIRED SET TOLERANCE FOR ENGINE INLET TOTAL PRESSURE, LBF/IN2
PAMTOL	DESIRED SET TOLERANCE FOR SIMULATED ALTITUDE AMBIENT (CELL) PRESSURE, LBF/IN2
T2TOL	DESIRED SET TOLERANCE FOR ENGINE INLET TOTAL TEMPERATURE, F
RPRTOL	DESIRED SET TOLERANCE FOR RAM PRESSURE RATIO, %
TPLTOL	MAXIMUM ALLOWABLE BELLMOUTH INLET PLENUM TEMPERATURE SPREAD, F
SP2TLP	ENGINE INLET TOTAL PRESSURE STABILITY CHECK TOLERANCE, %
SP2TLD	ENGINE INLET TOTAL PRESSURE STABILITY CHECK TOLERANCE, LBF/IN2
SPATLP	AMBIENT (CELL) PRESSURE STABILITY CHECK TOLERANCE, %
SPATLD	AMBIENT (CELL) PRESSURE STABILITY CHECK TOLERANCE, %
ST2TLP	ENGINE INLET TOTAL TEMPERATURE STABILITY CHECK TOLERANCE, %
ST2TLD	ENGINE INLET TOTAL TEMPERATURE STABILITY CHECK TOLERANCE, %
SPVTLP	VENTURI INLET PRESSURE STABILITY CHECK TOLERANCE, %
SPVTLD	VENTURI INLET PRESSURE STABILITY CHECK TOLERANCE, %
STVTLP	VENTURI INLET TEMPERATURE STABILITY CHECK TOLERANCE, %
STVTLD	VENTURI INLET TEMPERATURE STABILITY CHECK TOLERANCE, %
SN1TLP	LOW ROTOR SPEED STABILITY CHECK TOLERANCE, %
SN1TLD	LOW ROTOR SPEED STABILITY CHECK TOLERANCE, %
SN2TLP	HIGH ROTOR SPEED STABILITY CHECK TOLERANCE, %
SN2TLD	HIGH ROTOR SPEED STABILITY CHECK TOLERANCE, %
SFSTLP	THRUST LOAD CELL (SCALE FORCE) STABILITY CHECK TOLERANCE, %
SFSTLD	THRUST LOAD CELL (SCALE FORCE) STABILITY CHECK TOLERANCE, %
SAJTLP	EXHAUST NOZZLE AREA STABILITY CHECK TOLERANCE, %
SAJTLD	EXHAUST NOZZLE AREA STABILITY CHECK TOLERANCE, %
SWFFTP	FACILITY FUEL FLOWMETER STABILITY CHECK TOLERANCE, %
SWFFTD	FACILITY FUEL FLOWMETER STABILITY CHECK TOLERANCE, %
WFFMN	MINIMUM FACILITY FUEL FLOWMETER OUTPUT FOR STABILITY CHECK, HZ OR LBM H20/HR
FFMCD	FACILITY FUEL FLOWMETER OUTPUT CODE = 0.0 OUTPUT IN HZ > 0.0 OUTPUT IN LBM H20/HR
SWFETP	ENGINE FUEL FLOWMETER STABILITY CHECK TOLERANCE, %
SWFETD	ENGINE FUEL FLOWMETER STABILITY CHECK TOLERANCE, %
WFEOMN	MINIMUM ENGINE FUEL FLOWMETER OUTPUT FOR STABILITY CHECK, HZ OR LBM H20/HR
EFMCD	ENGINE FUEL FLOWMETER OUTPUT CODE = 0.0 OUTPUT IN HZ > 0.0 OUTPUT IN LBM H20/HR
SPLATL	POWER LEVER ANGLE STABILITY CHECK TOLERANCE, DEG
CLSBSW	LAB SEAL CONFIGURATION CONSTANT (1 = NO LAB SEAL, 2 = SINGLE DIRECTION LAB SEAL, 3 = DOUBLE DIRECTION LAB SEAL)
PLSBRF	DESIRED LAB SEAL BALANCE (DP ACROSS UPSTREAM AND DOWNSTREAM LANDS), %
PLSBTL	ACCEPTABLE TOLERANCE FOR DEVIATION FROM DESIRED LAB SEAL PRESSURE BALANCE, %
PLSCPT	LAB SEAL LAND PRESSURE CIRCUMFERENTIAL PROFILE TOLERANCE, %
PLSMAT	TOLERANCE FOR DIFFERENCE BETWEEN AVG. OF LAB SEAL LAND PRESSURES AND MANIFOLDED VALUE, %

DATVAL CONSTANTS (CONTINUED)

PARAMETER	DESCRIPTION
FSTOLP	TOLERANCE FOR DISAGREEMENT BETWEEN THRUST LOAD CELL BRIDGES, %
FSTOLD	TOLERANCE FOR DISAGREEMENT BETWEEN THRUST LOAD CELL BRIDGES, %
TTSTL	MAXIMUM ALLOWABLE THRUST STAND TEMPERATURE SPREAD, F
TLCCTL	MAXIMUM ALLOWABLE LOAD CELL COLUMN TEMPERATURE SPREAD, F
TMSCTL	MAXIMUM ALLOWABLE ENGINE SUPPORT CART TEMPERATURE SPREAD, F
FSMN	MINIMUM THRUST LOAD CELL CALIBRATION RANGE, LBF
FSMX	MAXIMUM THRUST LOAD CELL CALIBRATION RANGE, LBF
CFGTL	MAXIMUM ALLOWABLE DIFFERENCE BETWEEN CALCULATED AND PREDICTED THRUST COEFFICIENT, %
CD8TL	MAXIMUM ALLOWABLE DIFFERENCE BETWEEN CALCULATED AND PREDICTED EXHAUST NOZZLE DISCHARGE COEFFICIENT, %
FSCTL	CALIBRATE THRUST LOAD CELL ZERO TOLERANCE, LBF
WFTMN	MINIMUM FACILITY FLOWMETER FUEL FLOW FOR FLOWMETER CHECKS, LBM/HR
WFHMN	MINIMUM FUEL FLOW FOR RANGE CHECK OF HIGH-RANGE FACILITY FLOWMETERS, LBM/HR
WFMMN	MINIMUM FUEL FLOW FOR RANGE CHECK OF MID-RANGE FACILITY FLOWMETERS, LBM/HR
WFLMN	MINIMUM FUEL FLOW FOR RANGE CHECK OF LOW-RANGE FACILITY FLOWMETERS, LBM/HR
DWFFTP	MAXIMUM ALLOWABLE FUEL FLOW DISAGREEMENT BETWEEN SELECTED -1 AND -2 FACILITY FLOWMETERS, %
DWFFTD	MAXIMUM ALLOWABLE FUEL FLOW DISAGREEMENT BETWEEN SELECTED -1 AND -2 FACILITY FLOWMETERS, LBM/HR
WFEMN	MINIMUM ENGINE FLOWMETER FUEL FLOW FOR FLOWMETER CHECKS, LBM/HR
DWFTLP	MAXIMUM ALLOWABLE FUEL FLOW DISAGREEMENT BETWEENFACILITY AND ENGINE FLOWMETERS, %
DWFTLD	MAXIMUM ALLOWABLE FUEL FLOW DISAGREEMENT BETWEEN FACILITY AND ENGINE FLOWMETERS, LBM/HR
DWFETP	MAXIMUM ALLOWABLE FUEL FLOW DISAGREEMENT BETWEEN-1 AND-2 ENGINE FLOWMETERS, %
DWFETD	MAXIMUM ALLOWABLE FUEL FLOW DISAGREEMENT BETWEEN-1 AND -2 ENGINE FLOWMETERS, LBM/HR
TFTL1	MAXIMUM ALLOWABLE FUEL TEMPERATURE DISAGREEMENT BETWEEN LOW AND HIGH RANGE FACILITY FLOWMETERS, F
TFTL2	MAXIMUM ALLOWABLE FUEL TEMPERATURE DISAGREEMENT BETWEEN LOW AND MID RANGE FACILITY FUEL FLOWMETERS, F
TFTL3	MAXIMUM ALLOWABLE FUEL TEMPERATURE DISAGREEMENT BETWEEN LOW RANGE FACILITY FLOWMETER AND ENGINE INTERFACE (TFO), F
WFABTL	MAXIMUM ALLOWABLE DISAGREEMENT BETWEEN MEASURED AND PREDICTED A/B FUEL FLOW, %
TFTL4	MAXIMUM ALLOWABLE FUEL TEMPERATURE DISAGREEMENT BETWEEN MID AND HI RANGE FACILITY FLOWMETERS, F
TFTL5	MAXIMUM ALLOWABLE FUEL TEMPERATURE DISAGREEMENT BETWEEN MID-RANGE FLOWMETERS AND ENGINE INTERFAC (TFO), F
TFTL6	MAXIMUM ALLOWABLE FUEL TEMPERATURE DISAGREEMENT BETWEEN HI-RANGE FLOWMETERS AND ENGINE INTERFACE, F
TFTL7	MAXIMUM ALLOWABLE DISAGREEMENT BETWEEN REDUNDANT FACILITY FLOWMETER FUEL TEMPERATURE, F

DATVAL CONSTANTS (CONTINUED)

PARAMETER	DESCRIPTION
EFANTL	MAXIMUM ALLOWABLE DISAGREEMENT BETWEEN CALCULATED AND PREDICTED FAN EFFICIENCY, %
ECOMTL	MAXIMUM ALLOWABLE DISAGREEMENT BETWEEN CALCULATED AND PREDICTED COMPRESSOR EFFICIENCY, %
EBNTL	MAXIMUM ALLOWABLE DISAGREEMENT BETWEEN CALCULATED AND PREDICTED MAIN BURNER EFFICIENCY, %
EHPTTL	MAXIMUM ALLOWABLE DISAGREEMENT BETWEEN CALCULATED AND PREDICTED HP TURBINE EFFICIENCY, %
ELPTTL	MAXIMUM ALLOWABLE DISAGREEMENT BETWEEN CALCULATED AND PREDICTED LP TURBINE EFFICIENCY, %
EABTL	MAXIMUM ALLOWABLE DISAGREEMENT BETWEEN CALCULATED AND PREDICTED AUGMENTOR EFFICIENCY, %
ETBTL	MAXIMUM ALLOWABLE DISAGREEMENT BETWEEN CALCULATED AND PREDICTED OVERALL TURBINE EFFICIENCY, %
FIGVTL	MAXIMUM ALLOWABLE DEVIATION IN FAN INLET GUIDE VANE POSITION FROM CONTROL SCHEDULE, DEG
CIGVTL	MAXIMUM ALLOWABLE DEVIATION IN COMPRESSOR INLET GUIDE VANE POSITION FROM CONTROL SCHEDULE, DEG
A8TMTL	MAXIMUM ALLOWABLE DEVIATION IN EXHAUST NOZZLE TORQUE MOTOR VOLTAGE FROM ZERO, VOLTS
BTMTL	MAXIMUM ALLOWABLE DEVIATION IN AUGMENTOR TORQUE MOTOR VOLTAGE FROM ZERO, VOLTS
ETMTL	MAXIMUM ALLOWABLE DEVIATION IN MAIN ENGINE TORQUE MOTOR VOLTAGE FROM ZERO, VOLTS
FGVTMT	MAXIMUM ALLOWABLE DEVIATION IN FAN INLET GUIDE VANE TORQUE MOTOR VOLTAGE FROM ZERO, VOLTS
LTSPTL	MAXIMUM ALLOWABLE LP TURBINE INLET TEMPERATURE SPREAD (MAX-MIN), F
LTMXTL	MAXIMUM ALLOWABLE LP TURBINE INLET TEMPERATURE SPREAD (MAX-AVG), F
LTMNTL	MAXIMUM ALLOWABLE LP TURBINE INLET TEMPERATURE SPREAD (AVG-MIN), F
TINTL	MAXIMUM ALLOWABLE DISAGREEMENT BETWEEN INLET PLENUM AND ENGINE INLET TEMPERATURE, F
TLTIT1	MAXIMUM ALLOWABLE DISAGREEMENT BETWEEN LP TURBINE HARNESS AVG AND ARITHMETIC AVG INLET TEMPERATURE, F
TLTIT2	MAXIMUM ALLOWABLE DISAGREEMENT BETWEEN MEASURED AND CALCULATED LP TURBINE INLET TEMPERATURE, F
LTITLL	IF LTITA IS WITHIN THIS TOLERANCE OF LTITLM (SEE DATVAL INPUTS), LP TURBINE INLET TEMPERATURE MAY BE ON LIMIT, F
WBWVTL	MAXIMUM ALLOWABLE DISAGREEMENT BETWEEN BELLMOUTH AND VENTURI AIRFLOW, %
WLSW2T	MAXIMUM ALLOWABLE DISAGREEMENT BETWEEN AIRFLOW CALCULATED UPSTREAM OF LAB SEAL AND ENGINE INLET, %
WLDW2T	MAXIMUM ALLOWABLE DISAGREEMENT BETWEEN AIRFLOW CALCULATED DOWNSTREAM OF LAB SEAL AND ENGINE INLET, %
W2CMPT	MAXIMUM ALLOWABLE DISAGREEMENT BETWEEN MEASURED AND PREDICTED ENGINE INLET CORRECTED AIRFLOW, %
CODEV	CODEV = 0.0 VENTURI CLOSED/UNINSTALLED CODEV Ø 0.0 VENTURI INSTALLED/OPEN
PRVCH	VENTURI CHOKING PRESSURE RATIO, PUPSTREAM/PDOWNSTREAM
T2FMN	ENGINE INLET TEMPERATURE BELOW WHICH POTENTIAL EXISTS FOR ICING, F

DATVAL CONSTANTS (CONTINUED)

PARAMETER	DESCRIPTION
FSZATOLP	Tolerance for disagreement between vertical aft load cell bridges, %
FSZATOLD	Tolerance for disagreement between vertical aft load cell bridges, LBF
FSZFTOLP	Tolerance for disagreement between vertical forward load cell bridges, %
FSZFTOLD	Tolerance for disagreement between vertical forward load cell bridges, LBF
FSZMN	Minimum vertical thrust load cell calibration range, LBF
FSZMX	Maximum vertical thrust load cell calibration range, LBF
FSZACTL	Vertical aft calibrate thrust load cell zero tolerance, LBF
FSZFCTL	Vertical forward calibrate thrust load cell zero tolerance, LBF
THETETOL	Tolerance for disagreement between effective and geometric nozzle vector angles, DEG
THETDTOL	Tolerance for disagreement between demanded and geometric nozzle vector angles, DEG
CFISRF	Reference value for comparison with isolation seal calculated flow coefficient
CFISTL	Tolerance for disagreement between reference value and calculated isolation seal calculated flow coefficient
PISXRF	Reference value for comparison with total pressure loss from engine inlet duct inlet plenum to isolation seal, %
PISXTL	Tolerance for disagreement between reference value and total pressure loss from engine inlet duct inlet plenum to isolation seal, %
XISDCMN	Value of isolation seal duct contact parameter below which duct contact exists
XISDCMX	Value of isolation seal duct contact parameter above which duct contact exists
DUCDPIMN	Minimum upper closure door position indicator calibration value (percent open), %
DUCDPIMX	Maximum upper closure door position indicator calibration value (percent open), %
DLCDPIMN	Minimum lower closure door position indicator calibration value (percent open), %
DLCDPIMX	Maximum lower closure door position indicator calibration value (percent open), %
DSCDPIMN	Minimum side closure door position indicator calibration value (percent open), %
DSCDPIMX	Maximum side closure door position indicator calibration value (percent open), %
DUCDPITL	Tolerance for disagreement between upper closure door position indicators, %
DLCDPITL	Tolerance for disagreement between lower closure door position indicators, %
DSCDPITL	Tolerance for disagreement between side closure door position indicators, %
TKUCDREQ	Minimum number of upper closure door temperatures required for safe operation
TKLCDREQ	Minimum number of lower closure door temperatures required for safe operation
TKSCDREQ	Minimum number of side closure door temperatures required for safe operation
TKUCDMX	Maximum upper closure door temperature for safe operation, R
TKUCDMN	Minimum upper closure door temperature, R
TKLCDMX	Maximum lower closure door temperature for safe operation, R
TKLCDMN	Minimum lower closure door temperature, R
TKSCDMX	Maximum side closure door temperature for safe operation, R
TKSCDMN	Minimum side closure door temperature, R
TCELLMX	Maximum test cell temperature for safe operation, R
TCELLMN	Minimum test cell temperature, R
TCELLREQ	Minimum number of test cell temperatures required for safe operation
WCAMQMX	Maximum allowable ratio of test cell cooling airflow to engine inlet airflow to ensure accurate thrust measurement
PS0CGRMX	Maximum allowable circumferential test cell pressure gradient for accurate thrust measurement, %
PS0RGRMX	Maximum allowable radial test cell pressure gradient for accurate thrust measurement, %
PSVLCR	Venturi leak check system reference pressure, LBF/IN2
PSVLCTOL	Tolerance for disagreement between venturi leak check system reference pressure and individual venturi leak check pressures, LBF/IN2

DATVAL CONSTANTS (CONCLUDED)

PARAMETER	DESCRIPTION
UTRBOXTL	Tolerance for disagreement between UTR reference temperatures (in the same reference box), R
TMPREFTL	Tolerance for overall UTR reference temperature disagreement, R
TICEREF	Ice point verification reference temperature, R
TICETOL	Tolerance for disagreement between ice point verification reference temperature and ice point verification temperatures, R
FLTTOL	Tolerance for verification of APMS floating reference, LBF/IN2
VACTOL	Tolerance for verification of APMS vacuum reference, LBF/IN2
AMBTOL	Tolerance for verification of APMS ambient reference, LBF/IN2
AMBREF	Expected ambient reference pressure, LBF/IN2

DATAVAL INPUTS

PARAMETER	DESCRIPTION
P2	AS-TESTED ENGINE INLET TOTAL PRESSURE, LBF/IN2
P2D	DESIRED ENGINE INLET TOTAL PRESSURE, LBF/IN2
PAMB	AS-TESTED ALTITUDE AMBIENT (CELL) PRESSURE, LBF/IN2
PAMBD	DESIRED ALTITUDE AMBIENT (CELL) PRESSURE, LBF/IN2
T2	AS-TESTED ENGINE INLET TOTAL TEMPERATURE, F
T2D	DESIRED ENGINE INLET TOTAL TEMPERATURE, F
TPLMAX	MAXIMUM INLET PLENUM TEMPERATURE (PROFILE CHECK), F
TPLMIN	MINIMUM INLET PLENUM TEMPERATURE (PROFILE CHECK), F
P2MAX	MAXIMUM VALUE OF P2 DURING DATA POINT (STABILITY), LBF/IN2
P2MIN	MINIMUM VALUE OF P2 DURING DATA POINT (STABILITY), LBF/IN2
P2AVG	AVERAGE VALUE OF P2 DURING DATA POINT (STABILITY), LBF/IN2
PAMMX	MAXIMUM VALUE OF PAMB DURING DATA POINT (STABILITY), LBF/IN2
PAMMN	MINIMUM VALUE OF PAMB DURING DATA POINT (STABILITY), LBF/IN2
PAMAVG	AVERAGE VALUE OF PAMB DURING DATA POINT (STABILITY), LBF/IN2
T2MAX	MAXIMUM VALUE OF T2 DURING DATA POINT (STABILITY), R
T2MIN	MINIMUM VALUE OF T2 DURING DATA POINT (STABILITY), R
T2AVG	AVERAGE VALUE OF T2 DURING DATA POINT (STABILITY), R
PVMAX	MAXIMUM VALUE OF VENTURI INLET PRESSURE DURING DATA POINT (STABILITY), LBF/IN2
PVMIN	MINIMUM VALUE OF VENTURI INLET PRESSURE DURING DATA POINT (STABILITY), LBF/IN2
PVAVG	AVERAGE VALUE OF VENTURI INLET PRESSURE DURING DATA POINT (STABILITY), LBF/IN2
TVMAX	MAXIMUM VALUE OF VENTURI INLET TEMPERATURE DURING DATA POINT (STABILITY), R
TVMIN	MINIMUM VALUE OF VENTURI INLET TEMPERATURE DURING DATA POINT (STABILITY), R
TVAVG	AVERAGE VALUE OF VENTURI INLET TEMPERATURE DURING DATA POINT (STABILITY), R
N1MAX	MAXIMUM VALUE OF LOW ROTOR SPEED DURING DATA POINT (STABILITY), RPM
N1MIN	MINIMUM VALUE OF LOW ROTOR SPEED DURING DATA POINT (STABILITY), RPM
N1	AVERAGE VALUE OF LOW ROTOR SPEED DURING DATA POINT (STABILITY), RPM
N2MAX	MAXIMUM VALUE OF HIGH ROTOR SPEED DURING DATA POINT (STABILITY), RPM
N2MIN	MINIMUM VALUE OF HIGH ROTOR SPEED DURING DATA POINT (STABILITY), RPM
N2	AVERAGE VALUE OF HIGH ROTOR SPEED DURING DATA POINT (STABILITY), RPM
FS1MX	MAXIMUM VALUE OF THRUST LOAD CELL OUTPUT (BRIDGE #1) DURING DATA POINT (STABILITY), LBF
FS1MN	MINIMUM VALUE OF THRUST LOAD CELL OUTPUT (BRIDGE #1) DURING DATA POINT (STABILITY), LBF
FS2MN	MINIMUM VALUE OF THRUST LOAD CELL OUTPUT (BRIDGE #2) DURING DATA POINT (STABILITY), LBF
FS1	AVERAGE VALUE OF THRUST LOAD CELL OUTPUT (BRIDGE #1) DURING DATA POINT (STABILITY), LBF
FS2MX	MAXIMUM VALUE OF THRUST LOAD CELL OUTPUT (BRIDGE #2) DURING DATA POINT (STABILITY), LBF

DATAVAL INPUTS (CONTINUED)

PARAMETER	DESCRIPTION
FS2	AVERAGE VALUE OF THRUST LOAD CELL OUTPUT (BRIDGE #2) DURING DATA POINT (STABILITY), LBF
AJMX	MAXIMUM VALUE OF EXHAUST NOZZLE AREA DURING DATA POINT (STABILITY), FT2
AJMN	MINIMUM VALUE OF EXHAUST NOZZLE AREA DURING DATA POINT (STABILITY), FT2
AJ	AVERAGE VALUE OF EXHAUST NOZZLE AREA DURING DATA POINT (STABILITY), FT2
WFF1MX	MAXIMUM VALUE OF SELECTED FACILITY FUEL FLOWMETER #1 OUTPUT DURING DATA POINT (STABILITY), HZ OR LBM H20/HR
WFF1MN	MINIMUM VALUE OF SELECTED FACILITY FUEL FLOWMETER # 1 OUTPUT DURING DATA POINT (STABILITY), HZ OR LBM H20/HR
WFF01	AVERAGE VALUE OF SELECTED FACILITY FUEL FLOWMETER #1 OUTPUT DURING DATA POINT (STABILITY), HZ OR LBM H20/HR
WFF2MX	MAXIMUM VALUE OF SELECTED FACILITY FUEL FLOWMETER #2 OUTPUT DURING DATA POINT (STABILITY), HZ OR LBM H20/HR
WFF2MN	MINIMUM VALUE OF SELECTED FACILITY FUEL FLOWMETER #2 OUTPUT DURING DATA POINT (STABILITY), HZ OR LBM H20/HR
WFF02	AVERAGE VALUE OF SELECTED FACILITY FUEL FLOWMETER #2 OUTPUT DURING DATA POINT (STABILITY), HZ OR LBM H20/HR
WFE1MX	MAXIMUM VALUE OF ENGINE FUEL FLOWMETER #1 OUTPUT DURING DATA POINT (STABILITY), HZ OR LBM H20/HR
WFE1MN	MINIMUM VALUE OF ENGINE FUEL FLOWMETER #1 OUTPUT DURING DATA POINT (STABILITY), HZ OR LBM H20/HR
WFE01	AVERAGE VALUE OF ENGINE FUEL FLOWMETER #1 OUTPUT DURING DATA POINT (STABILITY), HZ OR LBM H20/HR
WFE2MX	MAXIMUM VALUE OF ENGINE FUEL FLOWMETER #2 OUTPUT DURING DATA POINT (STABILITY), HZ OR LBM H20/HR
WFE2MN	MINIMUM VALUE OF ENGINE FUEL FLOWMETER #2 OUTPUT DURING DATA POINT (STABILITY), HZ OR LBM H20/HR
WFE02	AVERAGE VALUE OF ENGINE FUEL FLOWMETER #2 OUTPUT DURING DATA POINT (STABILITY), HZ OR LBM H20/HR
PLAMX	MAXIMUM VALUE OF POWER LEVER POSITION DURING DATA POINT (STABILITY), DEG
PLAMN	MINIMUM VALUE OF POWER LEVER POSITION DURING DATA POINT (STABILITY), DEG
PLA	AVERAGE VALUE OF POWER LEVER POSITION DURING DATA POINT (STABILITY), DEG
PLSUAV	AVERAGE VALUE OF LAB SEAL UPSTREAM LAND BALANCING PRESSURES, LBF/IN2
PLSDAV	AVERAGE VALUE OF LAB SEAL DOWNSTREAM LAND BALANCING PRESSURES, LBF/IN2
PLSUMX	MAXIMUM VALUE OF LAB SEAL UPSTREAM LAND BALANCING PRESSURES (CIRCUMFERENTIAL PROFILE CHECK), LBF/IN2
PLSUMN	MINIMUM VALUE OF LAB SEAL UPSTREAM LAND BALANCING PRESSURES (CIRCUMFERENTIAL PROFILE CHECK), LBF/IN2
PLSDMX	MAXIMUM VALUE OF LAB SEAL DOWNSTREAM LAND BALANCING PRESSURES (CIRCUMFERENTIAL PROFILE CHECK) LBF/IN2
PLSDMN	MINIMUM VALUE OF LAB SEAL DOWNSTREAM LAND BALANCING PRESSURES (CIRCUMFERENTIAL PROFILE CHECK), LBF/IN2
PLSUM	LAB SEAL UPSTREAM LAND MANIFOLDED BALANCING PRESSURE LBF/IN2
PLSDM	LAB SEAL DOWNSTREAM LAND MANIFOLDED BALANCING PRESSURE, LBF/IN2

DATAVAL INPUTS (CONTINUED)

PARAMETER	DESCRIPTION
TTSMX	MAXIMUM THRUST STAND TEMPERATURE (SPREAD CHECK), F
TTSMN	MINIMUM THRUST STAND TEMPERATURE (SPREAD CHECK), F
TLCCMX	MAXIMUM THRUST LOAD CELL COLUMN TEMPERATURE (SPREAD CHECK), F
TLCCMN	MINIMUM THRUST LOAD CELL COLUMN TEMPERATURE (SPREAD CHECK), F
TMSCMX	MAXIMUM ENGINE SUPPORT CART TEMPERATURE (SPREAD CHECK), F
TMSCMN	MINIMUM ENGINE SUPPORT CART TEMPERATURE (SPREAD CHECK), F
CFGC	CALCULATED EXHAUST NOZZLE THRUST COEFFICIENT
CFGP	PREDICTED EXHAUST NOZZLE THRUST COEFFICIENT
CD8C	CALCULATED EXHAUST NOZZLE DISCHARGE COEFFICIENT
CD8P	PREDICTED EXHAUST NOZZLE DISCHARGE COEFFICIENT
P7	EXHAUST NOZZLE INLET TOTAL PRESSURE, LBF/IN2
XNPRCH	CHOKING VALUE OF EXHAUST NOZZLE PRESSURE RATIO
DFSB	SCALE FORCE ADJUSTMENT FOR OVERBOARD ENGINE BLEED FLOWS, LBF
DFSZS	SCALE FORCE ADJUSTMENT FOR THRUST LOAD CELL ZERO SHIFT, LBF
FSCLLC	CALIBRATE THRUST LOAD CELL OUTPUT, LBF
FSAVG	AVERAGE THRUST LOAD CELL OUTPUT, LBF
WFT	TOTAL ENGINE FUEL FLOW (FACILITY FLOWMETERS), LBM/HR
WFTH	HIGH-RANGE FACILITY FLOWMETER FUEL FLOW, LBM/HR
WFTM	MID-RANGE FACILITY FLOWMETER FUEL FLOW, LBM/HR
WFTL	LOW-RANGE FACILITY FLOWMETER FUEL FLOW, LBM/HR
FCODE	FACILITY FUEL FLOWMETER CODE (DETERMINES WHICH FLOWMETER RANGE SELECTED) 1.0 = LOW RANGE 2.0 = MID RANGE 0.0 = HIGH RANGE
WFT1	SELECTED FACILITY FLOWMETER #1 FUEL FLOW, LBM/HR
WFT2	SELECTED FACILITY FLOWMETER #2 FUEL FLOW, LBM/HR
WFAB	AUGMENTOR FUEL FLOW, LBM/HR
WFE	AVERAGE ENGINE FLOWMETER FUEL FLOW, LBM/HR (GAS GENERATOR)
WFE1	ENGINE FLOW METER #1 FUEL FLOW, LBM/HR (GAS GENERATOR)
WFE2	ENGINE FLOW METER #2 FUEL FLOW, LBM/HR (GAS GENERATOR)
TFLO	LOW-RANGE FACILITY FLOWMETER FUEL TEMPERATURE, F
TFMD	MID-RANGE FACILITY FLOWMETER FUEL TEMPERATURE, F
TFHI	HIGH RANGE FACILITY FLOWMETER FUEL TEMPERATURE, F
TFO	ENGINE INTERFACE FUEL TEMPERATURE, F
WFABP	PREDICTED AUGMENTOR FUEL FLOW, LBM/HR
TFE	ENGINE FLOWMETER FUEL TEMPERATURE, F
WFEAB	AUGMENTOR FUEL FLOW MEASURED BY ENGINE FLOWMETERS, LBM/HR
TF1	FACILITY FLOWMETER FUEL TEMPERATURE, F
TF2	FACILITY FLOWMETER FUEL TEMPERATURE, F
EFANC	CALCULATED FAN EFFICIENCY
EFANP	PREDICTED FAN EFFICIENCY
ECOMPC	CALCULATED HP COMPRESSOR EFFICIENCY
ECOMPP	PREDICTED HP COMPRESSOR EFFICIENCY
EBURNC	CALCULATED MAIN BURNER EFFICIENCY
EBURNP	PREDICTED MAIN BURNER EFFICIENCY
EHPTC	CALCULATED HP TURBINE EFFICIENCY
EHPTP	PREDICTED HP TURBINE EFFICIENCY
ELPTC	CALCULATED LP TURBINE EFFICIENCY
ELPTP	PREDICTED LP TURBINE EFFICIENCY
EABC	CALCULATED AUGMENTOR EFFICIENCY
EABP	PREDICTED AUGMENTOR EFFICIENCY

DATAVAL INPUTS (CONTINUED)

PARAMETER	DESCRIPTION
ETURBC	CALCULATED OVERALL TURBINE EFFICIENCY
ETURBP	PREDICTED OVERALL TURBINE EFFICIENCY
FIGV	FAN INLET GUIDE VANE POSITION, DEG
FIGVS	SCHEDULED FAN INLET GUIDE VANE POSITION, DEG
CIGV	HP COMPRESSOR INLET GUIDE VANE POSITION, DEG
CIGVS	SCHEDULED HP COMPRESSOR INLET GUIDE VANE POSITION, DEG
A8TMV	EXHAUST NOZZLE TORQUE MOTOR VOLTAGE, VOLTS
ABTMV	AUGMENTOR TORQUE MOTOR VOLTAGE, VOLTS
ETMV	MAIN ENGINE TORQUE MOTOR VOLTAGE, VOLTS
FGVTM	FAN INLET GUIDE VANE TORQUE MOTOR VOLTAGE, VOLTS
LTITMX	MAXIMUM LP TURBINE INLET TEMPERATURE (SPREAD CHECK), F
LTITMN	MINIMUM LP TURBINE INLET TEMPERATURE (SPREAD CHECK), F
LTITAV	AVERAGE LP TURBINE INLET TEMPERATURE (SPREAD CHECK), F
TPL	INLET PLENUM TEMPERATURE, F
LTITE	LP TURBINE INLET TEMPERATURE (ELECTRICAL HARNESS AVERAGE), F
LTITA	LP TURBINE INLET TEMPERATURE (ARITHMETIC AVERAGE), F
LTITC	CALCULATED LP TURBINE INLET TEMPERATURE, F
LTITLM	LP TURBINE INLET TEMPERATURE LIMIT, F
XMVT	VENTURI THROAT MACH NUMBER
PRV	PRESSURE RATIO ACROSS VENTURI, PUPSTREAM/PDOWNSTREAM (NOTE: IF PRV = 0.0, VENTURI THROAT MACH NO. WILL BE USED TO
WBM	BELLMOUTH AIRFLOW, LBM/SEC
WV	VENTURI AIRFLOW, LBM/SEC
WLSU	AIRFLOW CALCULATED UPSTREAM OF LAB SEAL, LBM/SEC
WA2	ENGINE INLET AIRFLOW, LBM/SEC
WLSD	AIRFLOW CALCULATED DOWNSTREAM OF LAB SEAL, LBM/SEC
WA2C2	ENGINE INLET CORRECTED AIRFLOW, LBM/SEC
W2C2P	PREDICTED ENGINE INLET CORRECTED AIRFLOW, LBM/SEC
PSLS	INLET DUCT STATIC PRESSURE AT LAB SEAL STATION, LBF/IN2
T2ICE	T2 BELOW WHICH INLET ICE FORMATION IS POSSIBLE, F
DPQPS	PRESSURE DROP (DP/P) ACROSS INLET PLENUM FOD SCREEN
DPQPMX	PRESSURE DROP (DP/P) LIMIT ABOVE WHICH FOD SCREEN ICING IS POSSIBLE
FSZACLLC	Vertical aft calibrate load cell output, LBF
FSZFCLLC	Vertical forward calibrate load cell output, LBF
FSZA1	Bridge #1 vertical aft load cell output, LBF
FSZA2	Bridge #2 vertical aft load cell output, LBF
FSZF1	Bridge #1 vertical forward load cell output, LBF
FSZF2	Bridge #2 vertical forward load cell output, LBF
THETV	Average nozzle geometric vector angle, LBF
THETDEV	Delta between effective and geometric nozzle vector angles, DEG
THETDMD	Demanded nozzle vector angle, DEG
CFISX	Calculated isolation seal flow coefficient using plenum total pressure
PISXQ	Total pressure loss from engine inlet duct inlet plenum to isolation seal, %
XISDC	Isolation seal duct contact parameter output
DUCDPI1	Upper closure door position indicator #1 value (percent open), %
DUCDPI2	Upper closure door position indicator #2 value (percent open), %
DLCDPI1	Lower closure door position indicator #1 value (percent open), %
DLCDPI2	Lower closure door position indicator #2 value (percent open), %
DSCDPI1	Side closure door position indicator #1 value (percent open), %
DSCDPI2	Side closure door position indicator #2 value (percent open), %
TKUCDNO	Number of non-zero upper closure door temperatures

DATAVAL INPUTS (CONCLUDED)

PARAMETER	DESCRIPTION
TKLCDNO	Number of non-zero lower closure door temperatures
TKSCDNO	Number of non-zero side closure door temperatures
TKUCDMAX	Maximum upper closure door temperature , R
TKUCDMIN	Minimum upper closure door temperature, R
TKLCDMAX	Maximum lower closure door temperature, R
TKLCDMIN	Minimum lower closure door temperature, R
TKSCDMAX	Maximum side closure door temperature, R
TKSCDMIN	Minimum side closure door temperature, R
TCELLMAX	Maximum test cell temperature, R
TCELLMIN	Minimum test cell temperature, R
TCELLNO	Number of non-zero test cell temperatures
WCAMQW1	Ratio of test cell cooling air to engine inlet airflow
PS0CGRAD	Circumferential test cell pressure gradient, (max-min)/avg x 100, %
PS0RGRAD	Radial test cell pressure gradient, (max-min)/avg x 100, %
PSVLCMAX	Maximum venturi leak check pressure, LBF/IN2
UTRDEVMX	Maximum deviation between UTR reference temperatures (in the same reference box), R
TMPREFDV	Overall deviation between UTR reference temperatures, R
TICEMAX	Maximum ice point verification temperature, R
QXZFLT	APMS floating reference Ruska pressure measurement, LBF/IN2
QXZAMB	APMS ambient reference Ruska pressure measurement, LBF/IN2
PSPLATM	APMS plenum reference pressure measured with atmospheric reference, LBF/IN2
PSOVAC	APMS cell pressure measured with the vacuum reference system, LBF/IN2
PSOATM	APMS cell pressure measured with the atmospheric reference system, LBF/IN2

DATVAL WARNING FLAGS

PARAMETER	DESCRIPTION
KP2D	AS-TESTED P2 OUT OF TOLERANCE IF KP2D = 1
KPAMBD	AS-TESTED PAMB OUT OF TOLERANCE IF KPAMBD = 1
KT2D	AS-TESTED T2 OUT OF TOLERANCE IF KT2D = 1
KRPRD	AS-TESTED RPR OUT OF TOLERANCE IF KRPRD = 1
KRPRN	SETTING NEGATIVE RPR IF KRPRN = 1
KTPLSP	TPL SPREAD OUT OF TOLERANCE IF KTPLSP = 1
KP2ST	P2 STABILITY EXCEEDS TOLERANCE IF KP2ST = 1
KPAMST	PAMB STABILITY EXCEEDS TOLERANCE IF PAMST = 1
KT2ST	T2 STABILITY EXCEEDS TOLERANCE IF KT2ST = 1
KPVST	PV STABILITY EXCEEDS TOLERANCE IF KPVST = 1
KTVST	TV STABILITY EXCEEDS TOLERANCE IF KTVST = 1
KN1ST	N1 STABILITY EXCEEDS TOLERANCE IF KN1ST = 1
KN2ST	N2 STABILITY EXCEEDS TOLERANCE IF KN2ST = 1
KFS1ST	FS1 STABILITY EXCEEDS TOLERANCE IF KFS1ST = 1
KFS2ST	FS2 STABILITY EXCEEDS TOLERANCE IF KFS2ST = 1
KAJST	AJ STABILITY EXCEEDS TOLERANCE IF KAJST = 1
KWFF1S	WFF01 STABILITY EXCEEDS TOLERANCE IF KWFF1S = 1
KWFF2S	WFF02 STABILITY EXCEEDS TOLERANCE IF KWFF2S = 1
KWFE1S	WFE01 STABILITY EXCEEDS TOLERANCE IF KWFE1S = 1
KWFE2S	WFE02 STABILITY EXCEEDS TOLERANCE IF KWFE2S = 1
KPLAST	PLA STABILITY EXCEEDS TOLERANCE IF KPLAST = 1
KLSB	LAB SEAL UNBALANCED IF KLSB = 1
KLSCPU	LAB SEAL (UPSTREAM LAND) CIRCUMFERENTIAL PRESSURE PROFILE EXCEEDS TOLERANCE IF KLSCPU = 1
KLSCPD	LABSEAL (DOWNSTREAM LAND) CIRCUMFERENTIAL PRESSURE PROFILE EXCEEDS TOLERANCE IF KLSCPD = 1
KLSMAU	DISAGREEMENT BETWEEN AVERAGE OF LAB SEAL (UPSTREAM LAND) PRESSURES AND MANIFOLDED VALUE EXCEEDS TOLERANCE IF KLSMAU = 1
KLSMAD	DISAGREEMENT BETWEEN AVERAGE OF LAB SEAL (DOWNSTREAM LAND) PRESSURES AND MANIFOLDED VALUE EXCEEDS TOLERANCE IF KLSMAD = 1
KTTS	THRUST STAND TEMPERATURE SPREAD EXCEEDS TOLERANCE IF KTTS = 1
KTLCC	THRUST LOAD CELL COLUMN TEMPERATURE SPREAD EXCEEDS TOLERANCE IF KTLCC = 1
KTMSC	ENGINE SUPPORT CART TEMPERATURE SPREAD EXCEEDS TOLERANCE IF KTMSC = 1
KFSCAL	THRUST LOAD CELL OUTPUT OUT OF CALIBRATION RANGE IF KFSCAL = 1
KCFG	DISAGREEMENT BETWEEN CALCULATED AND PREDICTED GROSS THRUST COEFFICIENT EXCEEDS TOLERANCE IF KCFG = 1
KCD8	DISAGREEMENT BETWEEN CALCULATED AND PREDICTED EXHAUST NOZZLE DISCHARGE COEFFICIENT EXCEEDS TOLERANCE IF KCD8
KNPR	EXHAUST NOZZLE IS UNCHOKED IF KNPR = 1
KFSBLD	SCALE FORCE IS BEING ADJUSTED FOR OVERBOARD ENGINE BLEED FLOW IF KFSBLD = 1
KFSZS	SCALE FORCE IS BEING ADJUSTED FOR LOAD CELL ZERO SHIFT IF KFSZS = 1
KFSCLC	THRUST CALIBRATE LOAD CELL OUTPUT EXCEEDS MAXIMUM ALLOWABLE DEVIATION FROM ZERO IF KFSCLC = 1
KFCHI	FUEL FLOW IS BELOW MINIMUM RATED LEVEL FOR HIGH-RANGE FACILITY FLOWMETERS IF KFCHI = 1
KFCMD	FUEL FLOW IS BELOW MINIMUM RATED LEVEL FOR MID-RANGE FACILITY FLOWMETERS IF KFCMD = 1

DATVAL WARNING FLAGS (CONTINUED)

PARAMETER	DESCRIPTION
KFCLO	FUEL FLOW IS BELOW MINIMUM RATED LEVEL FOR LOW-RANGE FACILITY FLOWMETER IF KFCLO = 1
KWFF12	DISAGREEMENT BETWEEN SELECTED FACILITY FUEL FLOWMETERS EXCEEDS TOLERANCE IF KWFF12 = 1
KWFFE	DISAGREEMENT BETWEEN FACILITY AND ENGINE FUEL FLOWMETERS EXCEEDS TOLERANCE IF KWFFE = 1
KWFE12	DISAGREEMENT BETWEEN ENGINE FUEL FLOWMETERS EXCEEDS TOLERANCE IF KWFE12 = 1
KTF	DISAGREEMENT IN FACILITY FLOWMETER FUEL TEMPERATURE EXCEEDS TOLERANCE IF KTF = 1
KFCODE	FUEL FLOW INDICATED THROUGH NEXT LOWER RANGE FACILITY FLOWMETERS FROM SELECTED RANGE METERS IF KFCODE = 1
KWFAB	DISAGREEMENT BETWEEN CALCULATED AND PREDICTED AUGMENTOR FUEL FLOW EXCEEDS TOLERANCE IF KWFAB = 1
KTFF	FACILITY FLOWMETER FUEL TEMPERATURE INPUT = 0 F IF KTFF = 1
KTFE	ENGINE FLOWMETER FUEL TEMPERATURE = 0 F IF KTFF = 1
KTF12	DISAGREEMENT BETWEEN REDUNDANT FACILITY FLOWMETER FUEL TEMPERATURE EXCEEDS TOLERANCE IF KTF12 = 1
KEFAN	DISAGREEMENT BETWEEN CALCULATED AND PREDICTED FAN EFFICIENCY EXCEEDS TOLERANCE IF KEFAN = 1
KECOMP	DISAGREEMENT BETWEEN CALCULATED AND PREDICTED HP COMPRESSOR EFFICIENCY EXCEEDS TOLERANCE IF KECOMP = 1
KEBURN	DISAGREEMENT BETWEEN CALCULATED AND PREDICTED MAIN BURNER EFFICIENCY EXCEEDS TOLERANCE IF KEBURN = 1
KEHPT	DISAGREEMENT BETWEEN CALCULATED AND PREDICTED HP TURBINE EFFICIENCY EXCEEDS TOLERANCE IF KEHPT = 1
KELPT	DISAGREEMENT BETWEEN CALCULATED AND PREDICTED LP TURBINE EFFICIENCY EXCEEDS TOLERANCE IF KELPT = 1
KEAB	DISAGREEMENT BETWEEN CALCULATED AND PREDICTED AUGMENTOR EFFICIENCY EXCEEDS TOLERANCE IF KEAB = 1
KETURB	DISAGREEMENT BETWEEN CALCULATED AND PREDICTED OVERALL TURBINE EFFICIENCY EXCEEDS TOLERANCE IF KETURB = 1
KFIGV	DIFFERENCE BETWEEN ACTUAL AND SCHEDULED FAN INLET GUIDE VANE POSITION EXCEEDS TOLERANCE IF KFIGV = 1
KCIGV	DIFFERENCE BETWEEN ACTUAL AND SCHEDULED HP COMPRESSOR INLET GUIDE VANE POSITION EXCEEDS TOLERANCE IF KCIGV = 1
KA8TM	EXHAUST NOZZLE TORQUE MOTOR VOLTAGE EXCEEDS MAXIMUM ALLOWABLE DEVIATION FROM 0 IF KA8TM = 1
KABTM	AUGMENTOR TORQUE MOTOR VOLTAGE EXCEEDS MAXIMUM ALLOWABLE DEVIATION FROM ZERO IF KABTM = 1
KMETM	MAIN ENGINE TORQUE MOTOR VOLTAGE EXCEEDS MAXIMUM ALLOWABLE DEVIATION FROM ZERO IF KMETM = 1
KFIGTM	FAN INLET GUIDE VANE TORQUE MOTOR VOLTAGE EXCEEDS MAXIMUM ALLOWABLE DEVIATION FROM ZERO IF KFIGTM = 1
KLTITS	LP TURBINE INLET TEMPERATURE SPREAD EXCEEDS TOLERANCE IF KLTITS = 1
KTPLT2	DIFFERENCE BETWEEN INLET PLENUM AND ENGINE INLET TEMPERATURE EXCEEDS TOLERANCE IF KTPLT2 = 1
KDTIT1	DIFFERENCE BETWEEN LP TURBINE INLET ELECTRICAL AND ARITHMETIC AVERAGE TEMPERATURE EXCEEDS TOLERANCE IF KDTIT1 = 1
KDTIT2	DIFFERENCE BETWEEN CALCULATED AND MEASURED LP TURBINE INLET TEMPERATURE EXCEEDS TOLERANCE IF KDTIT2 = 1
KLTIT	LP TURBINE INLET TEMPERATURE MAY BE ON LIMIT IF KLTIT = 1

DATVAL WARNING FLAGS (CONTINUED)

PARAMETER	DESCRIPTION
KVCH	VENTURI IS UNCHOKED IF KVCH = 1
KWBWV	DIFFERENCE BETWEEN BELLMOUTH AND VENTURI AIRFLOW CALCULATIONS EXCEEDS TOLERANCE IF KWBWV = 1
KWLSW2	DIFFERENCE BETWEEN AIRFLOW CALCULATED UPSTREAM OF LAB SEAL AND ENGINE INLET AIRFLOW EXCEEDS TOLERANCE IF KWLSW2 = 1
KWLDW2	DIFFERENCE BETWEEN AIRFLOW CALCULATED DOWNSTREAM OF LAB SEAL AND ENGINE INLET AIRFLOW EXCEEDS TOLERANCE IF KWLDW2 = 1
KW2CD	DISAGREEMENT BETWEEN CALCULATED AND PREDICTED ENGINE INLET CORRECTED AIRFLOW EXCEEDS TOLERANCE IF KW2CD = 1
KWINBL	AIR INBLEED THROUGH LAB SEAL POSSIBLE IF KWINBL = 1 (USE DRY TEST CELL COOLING AIR)
KICE	ENGINE INLET TOTAL TEMPERATURE BELOW MINIMUM VALUE FOR ICE FORMATION IF KICE = 1
KDPQPS	FOD SCREEN PRESSURE DROP EXCEEDS LIMIT IF KDPQPS = 1 (ICE FORMATION WARNING)
KFSZA12	Disagreement between vertical aft load cell bridges exceeds tolerance
KFSZF12	Disagreement between vertical forward load cell bridges exceeds tolerance
KFSZACAL	Vertical aft thrust load cell output out of calibration range
KFSZFCAL	Vertical forward thrust load cell output out of calibration range
KTHETDEV	Delta between effective and geometric nozzle vector angles exceeds tolerance
KTHETDMD	Delta between demanded and geometric nozzle angle exceeds tolerance
KFSZACLC	Vertical aft calibrate load cell output exceeds maximum allowable deviation from zero if KFSZACLC = 1
KFSZFCLC	Vertical forward calibrate load cell output exceeds maximum allowable deviation from zero if KFSZFCLC = 1
KCFISCK	Disagreement between reference value and calculated isolation seal flow coefficient exceeds tolerance
KPISXCK	Disagreement between reference value and total pressure loss from engine inlet duct inlet plenum to isolation seal exceeds tolerance
KISDC	Isolation seal duct contact if KISDC = 1.0
KUCDPCAL	Upper closure door position indicator out of calibration range
KLCDPCAL	Lower closure door position indicator out of calibration range
KSCDPCAL	Side closure door position indicator out of calibration range
KUCDPI12	Disagreement between upper closure door position indicators exceeds tolerance
KLCDPI12	Disagreement between lower closure door position indicators exceeds tolerance
KSCDPI12	Disagreement between side closure door position indicators exceeds tolerance
KTKUCDRQ	Number of upper closure door temperatures insufficient to ensure safe operation when KTKUCDRQ = 1
KTKLCDRQ	Number of lower closure door temperatures insufficient to ensure safe operation when KTKLCDRQ = 1
KTKSCDRQ	Number of side closure door temperatures insufficient to ensure safe operation when KTKSCDRQ = 1
KTKUCDMX	Upper closure door temperature exceeds limit for safe operation when KTKUCDMX = 1
KTKUCDMN	Upper closure door temperature below expected operating range when KTKUCDMN = 1
KTKLCDMX	Lower closure door temperature exceeds limit for safe operation when KTKLCDMX = 1
KTKLCDMN	Lower closure door temperature below expected operating range when KTKLCDMN = 1
KTKSCDMX	Side closure door temperature exceeds limit for safe operation when KTKLCDMX = 1

DATVAL WARNING FLAGS (CONCLUDED)

PARAMETER	DESCRIPTION
KTKSCDMN	Side closure door temperature below expected operating range when KTKLCDMN = 1
KTCELLMX	Test cell temperature exceeds limit for safe operation
KTCELLMN	Test cell temperature below expected operating range when KTCELLMN = 1
KTCELLRQ	Number of test cell temperatures insufficient for safe operation when KTCELLRQ = 1
KWCAMQW1	Maximum allowable ratio of test cell cooling airflow to engine inlet airflow to ensure accurate thrust measurement exceeded when KWCAMQW1 = 1
KPS0CGRD	Maximum allowable circumferential test cell pressure gradient for accurate thrust measurement exceeded when KPS0CGRD = 1
KPS0RGRD	Maximum allowable radial test cell pressure gradient for accurate thrust measurement when KPS0RGRD = 1
KVENTLK	Venturi vacuum pump leak detection system indicates leaking venturi(s) when KVENTLK = 1
KUTRBOX	Maximum allowable disagreement between UTR reference temperatures (in the same reference box) exceeded
KTMPREF	Maximum overall disagreement between reference temperatures exceeded
KICEPT	Disagreement between ice point verification reference temperature and ice point verification temperatures exceeds tolerance
KFLT	Disagreement between APMS floating reference verification pressures exceeds tolerance
KVAC	Disagreement between APMS vacuum reference verification pressures exceeds tolerance
KAMB	Disagreement between APMS ambient reference verification pressure and expected value exceeds tolerance

DATVAL OUTPUTS

PARAMETER	DESCRIPTION
DP2	DIFFERENCE BETWEEN AS-TESTED AND DESIRED P2, LBF/IN2
DPAM	DIFFERENCE BETWEEN AS-TESTED AND DESIRED PAMB, LBF/IN2
DT2	DIFFERENCE BETWEEN AS-TESTED AND DESIRED T2, ^oF
DRPR	DIFFERENCE BETWEEN AS-TESTED AND DESIRED RPR, %
TPLSPD	INLET PLENUM TEMPERATURE SPREAD, ^oF
P2STBD	ENGINE INLET TOTAL PRESSURE STABILITY, LBF/IN2
P2STBP	ENGINE INLET TOTAL PRESSURE STABILITY %
PAMSTD	CELL PRESSURE STABILITY, LBF/IN2
PAMSTP	CELL PRESSURE STABILITY, %
T2STBD	ENGINE INLET TOTAL TEMPERATURE STABILITY, ^oF
T2STBP	ENGINE INLET TOTAL TEMPERATURE STABILITY, %
PVSTBD	VENTURI INLET TOTAL PRESSURE STABILITY, LBF/IN2
PVSTBP	VENTURI INLET TOTAL PRESSURE STABILITY, %
TVSTBD	VENTURI INLET TOTAL TEMPERATURE STABILITY, ^oF
TVSTBP	VENTURI INLET TOTAL TEMPERATURE STABILITY, %
N1STBD	LOW ROTOR SPEED STABILITY, RPM
N1STBP	LOW ROTOR SPEED STABILITY, %
N2STBD	HIGH ROTOR SPEED STABILITY, RPM
N2STBP	HIGH ROTOR SPEED STABILITY, %
FS1SBD	THRUST LOAD CELL (BRIDGE #1) STABILITY, LBF
FS1SBP	THRUST LOAD CELL (BRIDGE #1) STABILITY, %
FS2SBD	THRUST LOAD CELL (BRIDGE #2) STABILITY, LBF
FS2SBP	THRUST LOAD CELL (BRIDGE #2) STABILITY, %
AJSTBD	EXHAUST NOZZLE AREA STABILITY, FT^2
AJSTBP	EXHAUST NOZZLE AREA STABILITY, %
WFF1SD	SELECTED FACILITY FUEL FLOWMETER #1 STABILITY, HZ OR LBM H20/HR
WFF1SP	SELECTED FACILITY FUEL FLOWMETER #1 STABILITY, %
WFF2SD	SELECTED FACILITY FUEL FLOWMETER #2 STABILITY, HZ OR LBM
WFF2SP	SELECTED FACILITY FUEL FLOWMETER #2 STABILITY, %
WFE1SD	ENGINE FUEL FLOWMETER #1 STABILITY, HZ OR LBM H20/HR
WFE1SP	ENGINE FUEL FLOWMETER #1 STABILITY, %
WFE2SD	ENGINE FUEL FLOWMETER #2 STABILITY, HZ OR LBM H20/HR
WFE2SP	ENGINE FUEL FLOWMETER #2 STABILITY, %
PLASTD	POWER LEVER POSITION STABILITY, DEG
LSBALU	LAB SEAL BALANCE, PUPSTREAM LAND - PDOWNSTREAM LAND/ PUPSTREAM LAND, %
PDPLSU	LAB SEAL CIRCUMFERENTIAL PRESSURE PROFILE (UPSTREAM LAND), %
PDPLSD	LAB SEAL CIRCUMFERENTIAL PRESSURE PROFILE (DOWNSTREAM LAND), %
DPLSUM	DIFFERENCE BETWEEN LAB SEAL ARITHMETIC AVG PRESSURE AND MANIFOLDED VALUE (UPSTREAM LAND), %
DPLSDM	DIFFERENCE BETWEEN LAB SEAL ARITHMETIC AVG PRESSURE AND MANIFOLDED VALUE (DOWNSTREAM LAND), %
DFSD	THRUST LOAD CELL BRIDGE DISAGREEMENT, LBF
DFSP	THRUST LOAD CELL BRIDGE DISAGREEMENT, %
DTTS	THRUST STAND TEMPERATURE SPREAD, ^oF
DTLCC	THRUST LOAD CELL COLUMN TEMPERATURE SPREAD, ^oF
DTMSC	ENGINE SUPPORT CART TEMPERATURE SPREAD, ^oF
DCFG	DIFFERENCE BETWEEN CALCULATED AND PREDICTED GROSS THRUST COEFFICIENT, %
DCD8	DIFFERENCE BETWEEN CALCULATED AND PREDICTED EXHAUST NOZZLE DISCHARGE COEFFICIENT, %
XNPR	EXHAUST NOZZLE PRESSURE RATIO

DATVAL OUTPUTS (CONTINUED)

PARAMETER	DESCRIPTION
DWFFP	DISAGREEMENT BETWEEN SELECTED FACILITY FUEL FLOWMETERS, %
DWFFD	DISAGREEMENT BETWEEN SELECTED FACILITY FUEL FLOWMETERS, LBM/HR
DWFP	DISAGREEMENT BETWEEN FACILITY AND ENGINE FUEL FLOWMETERS, %
DWFD	DISAGREEMENT BETWEEN FACILITY AND ENGINE FUEL FLOWMETERS, LBM/HR
DWFEP	DISAGREEMENT BETWEEN ENGINE FUEL FLOWMETERS, %
DWFED	DISAGREEMENT BETWEEN ENGINE FUEL FLOWMETERS, LBM/HR
DTF1	DISAGREEMENT BETWEEN LOW AND HIGH RANGE FLOWMETER FUEL TEMPS, ^{o}F
DTF2	DISAGREEMENT BETWEEN LOW AND MID-RANGE FLOWMETER FUEL TEMPS, ^{o}F
DTF3	DISAGREEMENT BETWEEN LOW-RANGE FLOWMETER AND ENGINE INTERFACE FUEL TEMPERATURE, ^{o}F
DWFAB	DISAGREEMENT BETWEEN MEASURED AND PREDICTED AUGMENTOR FUEL FLOW, %
DTF4	DISAGREEMENT BETWEEN MID AND HIGH-RANGE FLOWMETER FUEL TEMPS, ^{o}F
DTF5	DISAGREEMENT BETWEEN MID-RANGE FLOWMETER AND ENGINE INTERFACE FUEL TEMP, ^{o}F
DTF6	DISAGREEMENT BETWEEN HIGH RANGE FLOWMETER AND ENGINE INTERFACE FUEL TEMP, ^{o}F
DTF12	DIFFERENCE BETWEEN REDUNDANT FACILITY FLOWMETER FUEL TEMPERATURES, ^{o}F
DEFAN	DISAGREEMENT BETWEEN CALCULATED AND PREDICTED FAN EFFICIENCY, %
DECOMP	DISAGREEMENT BETWEEN CALCULATED AND PREDICTED HP COMPRESSOR EFFICIENCY,%
DEBURN	DISAGREEMENT BETWEEN CALCULATED AND PREDICTED MAIN BURNER EFFICIENCY, %
DEHPT	DISAGREEMENT BETWEEN CALCULATED AND PREDICTED HP TURBINE EFFICIENCY, %
DELPT	DISAGREEMENT BETWEEN CALCULATED AND PREDICTED LP TURBINE EFFICIENCY, %
DEAB	DISAGREEMENT BETWEEN CALCULATED AND PREDICTED AUGMENTOR EFFICIENCY, %
DETURB	DISAGREEMENT BETWEEN CALCULATED AND PREDICTED OVERALL TURBINE EFFICIENCY, %
DFIGV	DISAGREEMENT BETWEEN ACTUAL AND SCHEDULED FIGV, DEG
DCIGV	DISAGREEMENT BETWEEN ACTUAL AND SCHEDULED CIGV, DEG
LTITSP	LP TURBINE INLET TEMPERATURE SPREAD (MAX-MIN), ^{o}F
LTIMXD	LP TURBINE INLET TEMPERATURE SPREAD (MAX -AVG), ^{o}F
LTIMND	LP TURBINE INLET TEMPERATURE SPREAD (AVG-MIN), ^{o}F
DTPLT2	DIFFERENCE BETWEEN INLET PLENUM AND ENGINE INLET TOTAL TEMP, ^{o}F
DLTIT1	DIFFERENCE BETWEEN LP TURBINE INLET ELECTRICAL AND ARITHMETIC AVERAGE TEMP, ^{o}F
DLTIT2	DIFFERENCE BETWEEN CALCULATED AND MEASURED LP TURBINE INLET TEMP, ^{o}F
DLTIT	DIFFERENCE BETWEEN MEASURED LP TURBINE INLET TEMPERATURE (LTITA) AND LTIT LIMIT (LTITLM), F
DWBWV	DISAGREEMENT BETWEEN BELLMOUTH AND VENTURI AIRFLOW, %

DATVAL OUTPUTS (CONCLUDED)

PARAMETER	DESCRIPTION
DWLSW2	DISAGREEMENT BETWEEN AIRFLOW CALCULATED UPSTREAM OF LAB SEAL AND ENGINE INLET AIRFLOW, %
DWLDW2	DISAGREEMENT BETWEEN AIRFLOW CALCULATED DOWNSTREAM OF LAB SEAL AND ENGINE INLET AIRFLOW, %
DW2CMP	DIFFERENCE BETWEEN MEASURED AND PREDICTED ENGINE INLET CORRECTED AIRFLOW, %
DT2ICE	DIFFERENCE BETWEEN ENGINE INLET TOTAL TEMP AND MINIMUM VALUE FOR ICE FORMATION, ^{o}F
DFSZAD	Vertical aft thrust load cell bridge disagreement, LBF
DFSZAP	Vertical aft thrust load cell bridge disagreement, %
DFSZFD	Vertical forward thrust load cell bridge disagreement, LBF
DFSZFP	Vertical forward thrust load cell bridge disagreement, %
DTHETDMD	Delta between demanded and geometric nozzle vector angles, DEG
DCFISX	Disagreement between reference value and calculated isolation seal flow coefficient
DPISXQ	Disagreement between reference value and total pressure loss from engine inlet duct inlet plenum to isolation seal
DUCDPI	Disagreement between upper closure door position indicators, %
DLCDPI	Disagreement between lower closure door position indicators, %
DSCDPI	Disagreement between side closure door position indicators, %
DFLT	Disagreement between APMS floating reference Ruska pressure measurement and plenum reference pressure, LBF/IN2
DVAC	Disagreement between APMS vacuum verification pressures, LBF/IN2
DAMB	Disagreement between APMS ambient Ruska pressure measurement and expected value, LBF/IN2

DESCRIPTION OF DATA VALIDITY CHECKS

CHECK NO.	CONSTANTS	INPUTS	VALIDITY CHECK DESCRIPTION
1,2	P2TOL	P2, P2D	Checks as-tested P2 for Low or High out of tolerance from desired value
3,4	PAMTOL	PAMB, PAMBD	Checks as-tested PAMB for Low or High out of tolerance from desired value
5,6	T2TOL	T2, T2D	Checks as-tested T2 for Low or High out of tolerance from desired value
7,8	RPRTOL	RPR, RPRD	Checks as-tested RPR for Low or High out of tolerance from desired value
9	--	RPR	Checks for negative ram (RPR < 1)
10	TPLTOL(1)	TPLMAX, TPLMIN	Compares inlet plenum temperature spread (max-min) to maximum allowable value
11	TINLTL(1)	TPL, T2	Compares difference between TPL and T2 to maximum allowable difference
12	T2FMN(2)	T2, PAMB, PSLS	Check for potential inlet duct icing conditions to exist in the event of lab seal in-leakage
13	--	T2, T2ICE	Check for potential inlet duct icing conditions (if T2 ó T21CE)
14	--	DPQPS, DPQPMX	Checks inlet plenum FOD screen DP/P for possible screen icing (if DPQPS > DPQPMX)
15 16	SP2TLP(1) SP2TLD(1)	P2MAX, P2MIN, P2AVG	Checks P2 stability vs. maximum allowable value for data validity
17 18	SPATLD(1) SPATLP(1)	PAMMX, PAMMN, PAMAVG	Checks PAMB stability vs. maximum allowable value for data validity
19 20	ST2TLD(1) ST2TLP(1)	T2MAX, T2MIN, T2AVG	Checks T2(or TPL) stability vs. maximum allowable value for data validity
21 22	SPVTLD(1) SPVTLP(1)	PVMAX, PVMIN, PVAVG	Checks venturi inlet pressure stability vs. maximum allowable value for data validity
23 24	STVTLD(1) STVTLP(1)	TVMAX, TVMIN, TVAVG	Checks venturi inlet temperature stability vs. maximum allowable value for data validity
25 26	SN1TLD(1) SN1TLP(1)	N1MAX, N1MIN, N1	Checks low rotor speed stability vs maximum allowable value for data validity
27 28	SN2TLD(1) SN2TLP(1)	N2MAX, N2MIN, N2	Checks High rotor speed stability vs. maximum allowable value for data validity
29 30	SFSTLD(1) SFSTLP(1)	FS1MX, FS1MN, FS1	Checks thrust load cell (bridge1) stability vs. maximum allowable value for data validity
31 32	SFSTLD(1) SFSTLP(1)	FS2MX, FS2MN, FS2	Checks thrust load cell (bridge 2) stability vs. maximum allowable value for data validity

(1) Check not made if constant = 0.0
(2) Check not made if constant = -999.0

DESCRIPTION OF DATA VALIDITY CHECKS (CONTINUED)

CHECK NO.	CONSTANTS	INPUTS	VALIDITY CHECK DESCRIPTION
33 34	SAJTLD(1) SAJTLP(1)	AJMX, AJMN, AJ	Checks exhaust nozzle area stability vs. maximum allowable for data validity
35,37 36	SWFFTD(1) SWFFTP(1)	WFF1MX, WFF1MN, WFF01	Checks selected facility fuel flowmeter #1 stability vs. maximum allowable value for data validity
38,40 39	SWFFTD(1) SWFFTP(1)	WFF2MX, WFF2MN, WFF02	Checks selected facility fuel flowmeter #2 stability vs. maximum allowable for data validity
41,43 42	SWFETD(1) SWFETP(1)	WFE1MX, WFE1MN, WFE01	Checks engine fuel flowmeter #1 stability vs. maximum allowable for data validity
44,46 45	SWFETD(1) SWFETP(1)	WFE2MX, WFE2MN, WFE02	Checks engine fuel flowmeter #2 stability vs. maximum allowable for data validity
47	SPLATL(1)	PLAMX, PLAMN, PLA	Checks power lever angle stability vs. maximum allowable for data validity
48,49,50, 51,52,53	CLSBSW(3), PLSBRF, PLSBTL	PLSUAV, PLSDAV	Checks lab seal balance (DP/P) vs. desired value
54	PLSCPT(1)	PLSUAV, PLSUMX, PLSUMN	Checks lab seal upstream land pressure profile, (max- min)/avg, vs. maximum allowable value
55	PLSCPT(1)	PLSDAV, PLSDMX, PLSDMN	Checks lab seal downstream land pressure profile, (max-min)/avg, vs. maximum allowable value
56	PLSMAT(1)	PLSUAV, PLSUM	Compares difference between arithmetic average and manifolded value of lab seal upstream pressures to maximum allowable difference
57	PLSMAT(1)	PLSDAV, PLSDM	Same as test 56 for lab seal downstream land pressures
58 59	FSTOLD(1) FSTOLP(1)	FS1,FS2	Compares difference between thrust load cell bridges to maximum allowable difference
60	TTSTL(1)	TTSMX, TTSMN	Checks thrust stand temperature spread vs. maximum allowable value
61	TLCCTL(1)	TLCCMX TLCCMN	Checks thrust load cell column temperature spread vs. maximum allowable
62	TMSCTL(1)	TMSCMX, TMSCMN	Checks engine support cart temperature spread vs. maximum allowable
63	FSMN(4), FSMX(5)	FSAVG	Checks average thrust load cell output vs. minimum and maximum calibration range

(1) Check not made if constant = 0.
(3) Check not made if constant ≠ 2 or 3.
(4) Check not made if constant > -99999.
(5) Check not made if constant > 99999.

DESCRIPTION OF DATA VALIDITY CHECKS (CONTINUED)

CHECK NO.	CONSTANTS	INPUTS	VALIDITY CHECK DESCRIPTION
64	CFGTL(1)	CFGC,CFGP	Compares calculated thrust coefficient to predicted value
65	CD8TL(1)	CD8C,CD8P	Compares calculated exhaust nozzle discharge coefficient to predicted value
66	XNPRCH	P7, PAMB	Checks for unchoked exhaust nozzle
67	--	DFSB	Checks for adjustment to thrust load cell output due to overboard engine bleed flows
68	--	DFZS	Checks for adjustment to thrust load cell output due to load cell zero shift
69	FSCTL(1)	FSCLLC	Checks for calibrate thrust load cell output other than zero
70,71,72	WFTMN	FCODE, WFTM,WFTL	Checks next lower range facility fuel flowmeters from selected range meters for zero fuel flow indication
73,74,75	WFLMN, WFMMN	FCODE, WFTL, WFTM, WFTH	Checks selected facility fuel flowmeters vs. minimum flow range for accuracy
76 77	DWFFTP(1) DWFFTD(1)	WFT1,WFT2	Checks for agreement (within tolerance) between selected facility fuel flowmeters
78 79	DWFTLD(1) DWFTLP(1)	WFT,WFE, WFEAB	Checks for agreement (within tolerance) between engine and facility fuel flowmeters
80 81	DWFETD(1) DWFETP(1)	WFE1,WFE2	Checks for agreement (within tolerance) between engine fuel flowmeters
82,83,84, 85,86,87	TFTL1(1), TFTL2(1), TFTL3(1), TFTL4(1), TFTL5(1), TFTL6(1)	FCODE, TFL0(6), TFMD(6), TFHI(6), TFO	Compares selected facility flowmeter fuel temperature to higher range flowmeter fuel temperatures and/or engine interface fuel temperatures.
88,89,90	--	FCODE, TFL0(6), TFMD(6), TFHI(6)	Checks selected facility flowmeter fuel temperature for zero input
91	--	TFE(6)	Checks engine flowmeter fuel temperature zero input
92	TFTL7(1)	TF1, TF2	Checks redundant facility flowmeter fuel temperatures for agreement within tolerance
93	WFABTL(1)	WFAB, WFABP	Compares calculated and predicted augmentor fuel flow for agreement within tolerance
94	EFANTL(1)	EFANC, EFANP	Checks calculated vs. predicted fan efficiency for agreement within tolerance

(1) Check not made if constant = 0.
(6) Check not made if input = -999.

DESCRIPTION OF DATA VALIDITY CHECKS (CONTINUED)

CHECK NO.	CONSTANTS	INPUTS	VALIDITY CHECK DESCRIPTION
95	ECOMTL(1)	ECOMPC, ECOMPP	Checks calculated vs. predicted compressor efficiency for agreement within tolerance
96	EBNTL(1)	EBURNC, EBURNP	Checks calculated vs. predicted main burner efficiency for agreement within tolerance
97	EHPTTL(1)	EHPTC, EHPTP	Checks calculated vs. predicted HP turbine efficiency for agreement within tolerance
98	ELPTTL(1)	ELPTC, ELPTP	Checks calculated vs. predicted LP turbine efficiency for agreement within tolerance
99	EABTL(1)	EABC, EABP	Checks calculated vs. predicted augmentor efficiency for agreement within tolerance
100	ETBTL(1)	ETURBC, ETURBP	Checks calculated vs. predicted overall turbine efficiency for agreement within tolerance
101	FIGVTL(1)	FIGV, FIGVS	Compares measured vs. scheduled fan inlet guide vane position
102	CIGVTL(1)	CIGV, CIGVS	Compares measured vs. scheduled compressor inlet guide vane position
103	A8TMTL(1)	A8TMV	Checks exhaust nozzle torque motor voltage for non-zero output
104	ABTMTL(1)	ABTMV	Checks augmentor torque motor voltage for non-zero output
105	ETMTL(1)	ETMV	Checks main engine torque motor voltage for non-zero output
106	FGVTMT(1)	FGVTM	Checks fan inlet guide vane torque motor voltage for non-zero output
107	LTSPTL(1)	LTITMX, LTITMN	Checks LP turbine inlet temperature spread (max-min) vs. maximum allowable value
108	LTMXTL(1)	LTITMX, LTITAV	Checks LP turbine inlet temperature spread (max-avg) vs. maximum allowable value
109	LTMNTL(1)	LTITAV, LTITMN	Checks LP turbine inlet temperature spread (avg-min) vs. maximum allowable value
110	TLTIT1(1)	LTITE, LTITA	Compares electrical harness avg and arithmetic avg LP turbine inlet temperatures
111	TLTIT2(1)	LTITAV, LTITC	Compares measured and calculated LP turbine inlet temperatures
112	LTITLL(1)	LTITA, LTITLM	Compares measured LP turbine inlet temperature to max limit
113	CODEV(1),	PRV,XMVT PRVCH	Checks for unchoked venturi (if PRV = 0, venturi throat mach no., XMVT, used for check)
114	CODEV(1), WBWVTL(1)	WBM,WV	Compares bellmouth and venturi airflow calculations for agreement within tolerance

(1) Check not made if constant = 0.

DESCRIPTION OF DATA VALIDITY CHECKS (CONTINUED)

CHECK NO.	CONSTANTS	INPUTS	VALIDITY CHECK DESCRIPTION
115	WLSW2T(1)	WLSU,WA2	Compares inlet duct airflow calculated upstream of lab seal to engine inlet airflow
116	WLDW2T(1)	WLSD,WA2	Comapares inlet duct airflow calculated downstream of lab seal to engine inlet airflow
117	W2CMPT(1)	WA2C2, W2C2P	Compares calculated and predicted engine inlet corrected airflow
118 119	FSZATOLP (1) FSZATOLD (1)	FSZA1, FSZA2,	Compares difference between vertical aft load cell bridges to maximum allowable difference
120 121	FSZFTOLP (1) FSZFTOLD (1)	FSZF1, FSZF2	Compares difference between vertical fwd load cell bridges to maximum allowable difference
122	FSZMN, (4) FSZMX (5)	FSZA1, FSZA2	Compares vertical aft load cell output vs calibration range
123	FSZMN, (4) FSZMX (5)	FSZF1, FSZF2	Compares vertical fwd load cell output vs calibration range
124	FSZACTL(1)	FSZACLLC	Checks for non-zero vertical aft calibrate load cell output
125	FSZFCTL(1)	FSZFCLLC	Checks for non-zero vertical fwd calibrate load cell output
126	THETETOL (1)	THETDEV	Compares difference between effective and geometric vector angles to maximum allowable difference
127	THETDTOL (1)	THETDMD, THETV	Compares difference between demanded and geometric vector angles to maximum allowable difference
128	CFISRF CFISTL(1)	CFISX	Compares variation in calculated isolation seal flow coefficient from expected value
129	PISXRF PISXTL(1)	PISXQ	Compares variation in isolation seal total pressure loss from expected value
130	XISDCMN(4) XISDCMX(5)	XISDC	Checks for isolation seal contact
131	DUCDPIMN (4) DUCDPIMX (5)	DUCDPI1, DUCDPI2	Compares upper closure door position indication vs calibration range
132	DLCDPIMN (4) DLCDPIMX (5)	DLCDPI1, DLCDPI2	Compares lower closure position indication calibration range

(1) Check not made if constant = 0
(4) Check not made if constant < -99999
(5) Check not made if constant > 99999

DESCRIPTION OF DATA VALIDITY CHECKS (CONTINUED)

CHECK NO.	CONSTANTS	INPUTS	VALIDITY CHECK DESCRIPTION
133	DSCDPIMN (4) DSCDPIMX (5)	DSCDPI1, DSCDPI2	Compares side closure door position indication calibration range
134	DUCDPITL (1)	DUCDPI1, DUCDPI2	Compares difference between upper closure door position indicators to maximum allowable difference
135	DLCDPITL(1)	DLCDPI1, DLCDPI2	Compares difference between lower closure door position indicators to maximum allowable difference
136	DSCDPITL(1)	DSCDPI1, DSCDPI2	Compares difference between side closure door position indicators to maximum allowable difference
137	TKUCDREQ (1)	TKUCDNO	Checks for a sufficient number of upper closure door temperatures to ensure safe operation
138	TKLCDREQ (1)	TKLCDNO	Checks for a sufficient number of lower closure door temperatures to ensure safe operation
139	TKSCDREQ (1)	TKSCDNO	Checks for a sufficient number of side closure door temperatures to ensure safe operation
140	TKUCDMX (1)	TKUCDMAX	Checks to ensure upper closure door temperature limit is not exceeded to ensure safe operation
141	TKUCDMN (1)	TKUCDMIN	Checks to ensure upper closure door temperature is above minimum expected value for valid operation
142	TKLCDMX(1)	TKLCDMAX	Checks to ensure lower closure door temperature limit is not exceeded to ensure safe operation
143	TKLCDMN (1)	TKLCDMIN	Checks to ensure lower closure door temperature is above minimum expected value for valid operation
144	TKSCDMX(1)	TKSCDMAX	Checks to ensure side closure door temperature imit is not exceeded to ensure safe operation
145	TKSCDMN (1)	TKSCDMIN	Checks to ensure side closure door temperature is above minimum expected value for valid operation
146	TCELLMX(1)	TCELLMAX	Checks to ensure test cell temperature limit is not exceeded to ensure safe operation
147	TCELLMN(1)	TCELLMIN	Checks to ensure test cell temperature is above a minimum expected value for valid operation
148	TCELLREQ (1)	TCELLNO	Checks for a sufficient number of test cell temperatures to ensure safe operation
149	WCAMQMX (1)	WCAMQW1	Checks ratio of test cell cooling airflow to engine inlet airflow to ensure accurate thrust measurement
150	PS0CGRMX (1)	PS0CGRAD	Checks circumferential test cell pressure gradient to ensure accurate thrust measurement
151	PS0RGRMX (1)	PS0RGRAD	Checks radial test cell pressure gradient to ensure accurate thrust measurement
152	PSVLCR, PSVLCTOL (1)	PSVLCMAX	Checks for leaking venturis using vacuum pump system

(1) Check not made if constant = 0

DESCRIPTION OF DATA VALIDITY CHECKS (CONCLUDED)

CHECK NO.	CONSTANTS	INPUTS	VALIDITY CHECK DESCRIPTION
153	UTRBOXTL (1)	UTRDEVMX	Checks for disagreement between UTR reference temperatures in the same reference box
154	TMPREFTL (1)	TMPREFDV	Checks for overall disagreement between UTR reference temperatures
155	TICEREF, TICETOL(1)	TICEMAX, TICEMIN	Checks for disagreement between ice point verification temperatures and reference value
156	FLTTOL(1)	QXZFLT, PSPLAMB	Checks for disagreement between APMS floating reference Ruska measurement and plenum reference pressure
157	VACTOL(1)	PSOVAC, PSOATM	Checks for disagreement between APMS vacuum verification pressures
158	AMBTOL(1), AMBREF	QXZAMB	Checks for disagreement between APMS ambient reference Ruska measurement and expected value

APPENDIX D. EXAMPLE TEST PERIOD DATA VERIFICATION PLAN

DATA VERIFICATION PLAN

FXXX-YY-XXX

J-1 Test Cell, Job 00000

Date last modified on [Month DD, YYYY] by ABC

In order to ensure the quality and accuracy of data acquired during the subject test program, the following steps will be followed for each test period:

Air-off (pre-test)

1. Steady-state data will be acquired at ambient conditions. Pressure and temperature measurements will be compared to ambient levels and should be within acceptable tolerances. Discrepancies will be communicated to ATA and customer personnel to determine if corrective action is required prior to going air-on. Discrepant measurements which are deemed non-critical (no action required) will be "zeroed out" in the data reduction programs (if necessary) and entered into the discrepancy data base.

2. A 30-sec transient data point will be acquired at ambient conditions. All data channels will be evaluated for noise, and etc. Discrepancies will be communicated to ATA and customer personnel to determine if corrective action is required prior to going air-on. Discrepant measurements which are deemed non-critical (no action required) will be "zeroed out" in the data reduction programs (if necessary) and entered into the discrepancy data base.

3. Bridge zero offsets for the thrust data load cell (FA1, FA2) and thrust calibrated load cell (FAC1, FAC2) will be determined from the ambient steady-state data described in (1) and inputted into the data reduction programs if necessary. Test cell ambient pressure (PAMBAVG) and data load cell temperature (TKDLCAVG) at this ambient condition will be inputted into the data reduction programs and will serve as reference values (PRCAL and TFACAL) for subsequent load cell pressure and temperature corrections.

4. The data reduction programs will be updated with fuel properties from the latest available fuel sample (viscosity (CVSFUEL), relative density (RD60FS), lower heating value (FLHV)).

Thrust Stand In-line Calibration Check (pre-test)

1. Transient data will be acquired during the application of load to the thrust stand through the in-line calibrator system (thrust stand sweep). The difference between the applied calibrator load (FACZAVG) and the data load cell output (FAZAVG), defined as the thrust stand tare (TAREFAZAVG), should be approximately linear with applied load, and the tare level approximately 0.1 percent of the applied load. The hysteresis in tare between increasing and decreasing load application should be less than 20 lbf.

2. Results of the tare characteristics shall be compared to results obtained during the previous test period and shall be reported to the ATA project engineer prior to going air-on.

3. A permanent history file shall be kept for all in-line calibrations performed on this project.

Air-on (vacuum check – prior to engine start)

1. Transient data will be taken while evacuating the test cell in preparation to performing a “vacuum check”. Aerodynamic pressures and individual pressure transducers will be evaluated for response characteristics during the “cell pump down”.

2. Ensure facility inlet valve is “sealed” during the pump down to vacuum conditions by observing engine rotor speed (ensure no rotation).

3. Upon establishing stable conditions at vacuum check conditions, acquire steady-state data. Check for leaks to atmosphere by comparing all pressure measurements on the NETSCAN System to the NETSCAN floating reference (#NETSCAN1_FLT). All aerodynamic pressures on the NETSCAN brick pressure systems should agree with the vacuum pressure level to within their respective measurement uncertainties. Individual close-coupled transducers should also agree with the vacuum pressure level to within their respective uncertainties.

4. Compare individual pressure transducer measurements to aerodynamic pressures to which they are “teed” for agreement. Agreement should be within quoted transducer uncertainties.

5. Verify unused ports on floating reference NETSCAN modules are within +/- 4 psid of #NETSCAN1_FLT at all times during the air period to ensure the modules do not “over-range”.

6. Verify corrected thrust data load cell output (FSCORR) is within +/- 10 lbf of zero at vacuum condition. This will ensure that the load cell pressure effects correction has been implemented correctly. If FSCORR does not meet this criterion, check with ATA projects engineer to ensure that the inlet air valve has a good seal.

7. Communicate all discrepancies to ATA and customer personnel to determine if corrective actions are required prior to starting the engine.

Air-on (engine running)

1. Use of EDAPS annunciator panel displays provide real-time assessment of data quality for selected parameters calculated in the DEU data reduction program (pressure distortions, temperature spreads, etc). These displays provide visibility of instrumentation status prior to acquisition of data.

2. Several automated data checks are performed in the steady-state data reduction program. Warning messages are printed out at the front of each data point when specified criteria (based on experience and/or previous test data) are not met.

3. Use of data verification plots set up on SGI workstation (TIGER) provide a convenient way to compare data from the current test period to a much larger data base (previous test periods, other test projects).

4. Some examples of the data verification checks alluded to in steps 1) - 3) are described below:

a. Several aerodynamic pressure measurements made on the NETSCAN Floating Reference System (e.g. PTPL1D, PSPL2) are tee'd to the atmospheric reference system (e.g. PTPL1DA, PSPL2A). These measurements should agree within their respective measurement uncertainties. Several aerodynamic pressure measurements made on the NETSCAN Floating Reference System (e.g. PTPL1C, PSPL1) are tee'd to the close coupled transducers (e.g. PTPL1CT, PSPL1T). These measurements should also agree within their respective measurement uncertainties

b. (Max-Min)/Avg distortion of multiple pressure measurements at a given facility or engine location.

c. (Max-Min) spread of multiple temperature measurements at a given facility or engine location.

d. Agreement between redundant facility and engine fuel flowmeter outputs.

e. Agreement between thrust data load cell output bridges.

f. Agreement between redundant inlet airflow measurements (venturi, bellmouth, inlet duct isolation seal, station 0.5)

g. Comparison between engine control parameters from the engine controler data buss and comparable parameters from other data sources (GPAD, NEFF, NETSCAN, DSA, etc.)

5. Instrumentation discrepancies identified during testing will be communicated to the customer and ATA project engineer to determine if corrective action is required. If discrepant instrumentation is deemed non-critical (no action required), it will be "zeroed out" in the data reduction programs.

6. Monitor PSCANREF to ensure the parameter is within +/- 0.015 psid of #NETSCAN1_ATM.

7. Monitor unused ports on floating reference NETSCAN modules are within +/- 4 psid of #NETSCAN1_FLT at all times during testing to ensure modules do not "over-range".

<u>Air-off (post-test)</u>

1. Acquire steady-state data point at ambient conditions following engine shutdown at end of test period. Check integrity of facility and engine instrumentation with the knowledge that the test cell and engine may not yet be at thermal equilibrium.

2. Enter all known instrumentation discrepancies into the EDAPS system. Coordinate discrepancies input and priority assignment with the customer and ATA project engineer.

Review status of all data/instrumentation discrepancies prior to next test period.

APPENDIX E. SUGGESTION FOR STANDARDIZATION OF PRINT PAGES

Table of Contents

The first page available for editing should include a Table of Contents

****
TABLE OF CONTENTS
****

Summary Page

Page two should contain a summary of your current and desired test conditions, critical engine parameters, critical facility parameters, and comparisons of TETAS and user performance parameters.

FACILITY SET CONDITIONS

	TARGET	FACILITY SET	CONTROL SENSED	TIME VARIANCE %	FACILITY SET DELTA	CONTROL SENSE DELTA	
ALT	0.00	0.00	0.00	-	0.00	-	FT
XM0	0.00	0.00	0.00	-	0.00	0.00	%
P2	0.00	0.00	0.00	0.00	0.00	0.00	%
PS0	0.00	0.00	0.00	0.00	0.00	0.00	%
T2	0.00	0.00	0.00	0.00	0.00	0.00	DEG F

ENGINE SET CONDITIONS

	FACILITY MEASURED	CONTROL SENSED	TIME VARIANCE %
PLA	0.00	0.00	-
N1	0.00	0.00	0.00
N1R	0.00	0.00	-
N2	0.00	0.00	0.00

INLET MOISTURE

RH	0.00
RATIO	0.00
GRAINS/LB	0.00

VENTURIS

NVOPEN	0.00
PRVENBH	0.00
XM-THROAT	0.00

CELL COOLING

TCAM	0.00
TACA	0.00
WACC	0.00

FUEL SYSTEM

PFX0	0.00
TF3	0.00
TF4	0.00
WFT	0.00

ENGINE PERFORMANCE SUMMARY

	AS-TESTED	REFERRED
W2	0.00	0.00
FN	0.00	0.00
RIT(R)	0.00	0.00
TSFC	0.00	

POWER EXTRACTION

ETRQWB	ETRQWB	PWXWB	PWXWB
XNWBC	XNWBC	ZHPXTOT	ZHPXTOT

CUSTOMER BLEED

PHPBOU	0.00	THPBOU	0.00
PHPBOD	0.00	WCBOR	0.00

DATA REDUCTION AND SIMULATION COMPARISONS

	AEDC TETAS	USER NPSS	DATA RED DELTA(%)	NPSS SIM DELTA(%)
P2	0.00	0.00	0.00	0.00
P125	0.00	0.00	0.00	0.00
P25	0.00	0.00	0.00	0.00
P3	0.00	0.00	0.00	0.00
P49	0.00	0.00	0.00	0.00
T2(R)	0.00	0.00	0.00	0.00
T125(R)	0.00	0.00	0.00	0.00
T25(R)	0.00	0.00	0.00	0.00
T3(R)	0.00	0.00	0.00	0.00
T41(R)	0.00	0.00	0.00	0.00
T49(R)	0.00	0.00	0.00	0.00
W2A	0.00	0.00	0.00	0.00
W24	0.00	0.00	0.00	0.00
P124Q2	0.00	0.00	0.00	0.00
P3Q24	0.00	0.00	0.00	0.00
EPR	0.00	0.00	0.00	0.00
EFAN	0.00	0.00	0.00	0.00
EHPC	0.00	0.00	0.00	0.00
WFB	0.00	0.00	0.00	0.00
WFAB	0.00	0.00	0.00	0.00
FN	0.00	0.00	0.00	0.00
TSFC	0.00	0.00	0.00	0.00

ENGINE CONTROL SUMMARY

	CONTROL SENSED	SENSOR DELTA	REQUEST DELTA	MIN LIM DELTA	MAX LIM DELTA
N1	0.00	0.00	-	-	0.00
N1R	0.00	0.00	-	0.00	-
N2	0.00	0.00	-	0.00	-
FVV	0.00	0.00	0.00	-	-
CVV	0.00	0.00	0.00	-	-
FDB	0.00	-	0.00	-	-
A8	0.00	-	0.00	-	-
P25	0.00	0.00	-	-	-
P3	0.00	0.00	-	-	-
PS32	0.00	0.00	-	-	0.00
P49	0.00	0.00	-	-	-
T25	0.00	0.00	-	-	-
T3	0.00	0.00	-	-	0.00
T41	0.00	0.00	-	-	0.00
T49	0.00	0.00	-	-	-
T6	0.00	0.00	-	-	0.00
FPR	0.00	0.00	-	-	-
EPR	0.00	0.00	0.00	-	-
LPR	0.00	0.00	-	0.00	-
WA2R	0.00	0.00	-	-	-
WFB	0.00	0.00	0.00	-	-
WFAB	0.00	0.00	-	-	-
WFTR	0.00	0.00	0.00	-	-

XLDV Check Flags

XLDV flags should be incorporated into the print pages. Flags should be located in a summary block in the lower right hand corner of each page.

```
----------------------------------------------------FACILITY INLET SYSTEM----------------------------------------------------
    VENTURI   PV___A     PSVT___    PVLD___    TKV___     TV___A     TV___B     TV___C     V__OPEN    WV___A     WV___I
        A02       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
        A04       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
        A06       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
        A08       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
        A10       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
        A12       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
        A14       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
        A16       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
        A18       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
        A20       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
        A22       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00

|-----------------------8' PLENUM-----------------------||------BELLMOUTH------||--------FACILITY INLET SYSTEM SUMMARY--------|
             1 (045)    2 (135)    3 (225)    4 (315)    PSBE1-4    PSLS1-4   | SURVEYS:       AVERAGE  DISTORTION       FLAG
PT IMMERS A      0.00       0.00       0.00       0.00       0.00       0.00 |  PV               0.00       0.00       0.00
          B      0.00       0.00       0.00       0.00       0.00       0.00 |  PSVT(OPE]        0.00       0.00       0.00
          C      0.00       0.00       0.00       0.00       0.00       0.00 |  PTPL             0.00       0.00       0.00
          D      0.00       0.00       0.00       0.00       0.00       0.00 |  PTPLT            0.00       0.00       0.00
          E      0.00       0.00       0.00       0.00    PSBE1T     PSLS01T  |  PSPL             0.00       0.00       0.00
      PSPL_      0.00       0.00       0.00       0.00       0.00       0.00 |  PSBE             0.00       0.00       0.00
                C          D          D          C                           |  PSLS             0.00       0.00       0.00
    PTPL__T   PTPL1CT    PTPL2DT    PTPL3DT    PTPL4CT  GRID/SCREEN DELTA-P'S |  TV               0.00       0.00       0.00
     PSPL_T    PSPL1T                                   DP20GUSX          0.00 |  TKV              0.00       0.00       0.00
                                                        DP20GDSX          0.00 |  TPL              0.00       0.00       0.00
TT IMMERS A      0.00       0.00       0.00       0.00 DP8SCRX           0.00 | STA. RATIO T/N              RATIO       FLAG
          B      0.00       0.00       0.00       0.00                         |        PTPL                  1.00       0.00
          C      0.00       0.00       0.00       0.00   PARTICLE DETECTION    |        PSPL                  1.00       0.00
          D      0.00       0.00       0.00       0.00 EPDS              0.00 |        PSBE                  1.00       0.00
          E      0.00       0.00       0.00       0.00                         |        PSLS                  1.00       0.00
 DUCT METAL   TKPL_      TK101-_     TK1-_              --- AIRFLOW SUMMARY -- |        PAMB                  1.00       0.00
       1.00      0.00       0.00       0.00            NVOPEN            0.00 | PSBEQLS                     1.00       0.00
       2.00      0.00       0.00       0.00            PRVENBH           0.00 | NETSCAN REF DELTAS:         DELTA       FLAG
                                                        XMVAVG            0.00 |    15-ATM VS. 5-FLT          0.00       0.00
-----------------HYGROMETER-----------------            WAVAPT            0.00 |    50-ATM VS. 5-FLT          0.00       0.00
PDPHYG           0.00 HUMRAT           0.00            WAVIPT            0.00 |    100-ATM VS. 5-FLT         0.00       0.00
TDPHYG           0.00 HUMGRN           0.00            WAVESV            0.00 |    PSPL AVG FROM REF         0.00       0.00
                                                        DVWVT             0.00 |    VENTURI LEAK DETE         0.00       0.00
|--------------PRESSURE VERIFICATION TEE'S--------------|WAVSEL            0.00 | FLOW RATIOS:                RATIO       FLAG
              PTPL1D     PTPL4D     PSLS01    DP___MX WABMLS            0.00 |    B/M TO VENTURI            1.00       0.00
    5-FLOAT      0.00       0.00       0.00       -    WABMBE            0.00 |    B/M PSBE-TO-PSLS          1.00       0.00
15-ATM (_Y)      0.00       0.00       0.00       0.00 WABM10            0.00 |    P&W STA 1000 TO P         1.00       0.00
50-ATM (_X)      0.00       0.00       0.00       0.00 WABMSL            0.00 |    BELLMOUTH CC/SS           1.00       0.00
.00-ATM (_Z)     0.00       0.00       0.00       0.00 WA1               0.00
```

Pressure Summary

A summary of pressures should be included. These can either be organized alphabetically or by pressure scanning measurement unit.

Netscann Brick Summary and Verification

	Module 24 (100 lb ATM)		Module 30 (100 lb ATM)		Module 31 (100 lb ATM)		Module 35 (750 lb ATM)		Module 101 (15 lb FLT)	
1	–	–	–	–	P254	0.00	–	–	PSPL1	0.00
2	PCPCF-R	0.00	–	–	–	–	PBLDOU	0.00	PSPL2	0.00
3	PS252	0.00	–	–	–	–	PBLDOD	0.00	PSPL3	0.00
4	P131	0.00	–	–	–	–	PSIGN-O	0.00	PSPL4	0.00
5	PCPDS-R	0.00	–	–	P133	0.00	–	–	PTPL1A	0.00
6	–	–	–	–	–	–	–	–	PTPL1B	0.00
7	P251	0.00	–	–	–	–	–	–	PTPL1C	0.00
8	–	–	–	–	P255	0.00	–	–	PTPL1D	0.00
9	–	–	–	–	–	–	–	–	PTPL1E	0.00
10	–	–	P252	0.00	–	–	–	–	PTPL2A	0.00
11	–	–	P132	0.00	PS251	0.00	PSAP	0.00	PTPL2B	0.00
12	–	–	–	–	P134	0.00	–	–	PTPL2C	0.00
13	–	–	–	–	–	–	–	–	PTPL2D	0.00
14	–	–	P253	0.00	–	–	–	–	PTPL2E	0.00
15	–	–	–	–	P256	0.00	–	–	PTPL3A	0.00
16	–	–	–	–	–	–	–	–	PTPL3B	0.00

	Module 102 (15 lb FLT)		Module 103 (750 lb ATM)		Module 104 (45 lb ATM)		Module 105 (45 lb ATM)		Module # (## lb ATM)	
1	PSLS01	0.00	P221	0.00	PVA02A	0.00	PVA14A	0.00	–	–
2	PTPL3C	0.00	P222	0.00	PSVTA02	0.00	PSVTA14	0.00	–	–
3	PTPL3D	0.00	P223	0.00	PVA04A	0.00	PVA16A	0.00	–	–
4	PTPL3E	0.00	P224	0.00	PSVTA04	0.00	PSVTA16	0.00	–	–
5	PTPL4A	0.00	P225	0.00	PVA06A	0.00	PVA18A	0.00	–	–
6	PTPL4B	0.00	P226	0.00	PSVTA06	0.00	–	–	–	–
7	PTPL4C	0.00	P227	0.00	–	–	PSVTA18	0.00	–	–
8	PTPL4D	0.00	P228	0.00	–	–	–	–	–	–
9	PTPL4E	0.00	P229	0.00	PVA08A	0.00	PVA20A	0.00	–	–
10	PSBE1	0.00	P230	0.00	–	–	–	–	–	–
11	PSBE2	0.00	P231	0.00	PSVTA08	0.00	–	–	–	–
12	PSBE3	0.00	P232	0.00	PVA10A	0.00	PSVTA20	0.00	–	–
13	PSBE4	0.00	P233	0.00	PSVTA10	0.00	–	–	–	–
14	PSLS02	0.00	–	–	PVA12A	0.00	PVA22A	0.00	–	–
15	PSLS03	0.00	–	–	–	–	–	–	–	–
16	PSLS04	0.00	NETSCAN_SUP	0.00	PSVTA12	0.00	PSVTA22	0.00	–	–